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The Effect of the Functional Linguistics of Mathematics Instruction (FLMI) Model on Quadratic Application Skills in Algebra

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DEDICATION

To my husband, who has exhibited extraordinary patience and support;

To my father, who taught me never to skip the word problems;

To my mother, who covered me in prayer;

To my brother, who will never let me give up on my future or forget my beginnings;

To Dr. Susan Wilk, who inspired my educational pursuits;

And, to my students and colleagues, without whom this process could not have been completed.

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ABSTRACT

This paper addresses a need for change in instructional practices to improve student performance in transferring of mathematical concepts to mathematical applications in Algebra 2 classes at Burdine High School (BHS) in South Carolina. The teacher-researcher has created a mathematics literacy instructional model, the Functional Linguistics of Mathematics Instruction model, which was implemented during an instructional unit on quadratic functions. A mixed methods design with an action research approach was utilized to determine the effects of this model on students' performance on an application-based assessment. Preliminary findings suggest initial success with the model as a remedy for applied mathematics shortcomings among Algebra 2 students at BHS. Reflections, suggestions for further research, and a step-by-step action plan for direct implementation as a result of this study are discussed. This paper serves as the communication of this study's conceptual framework, design, research context, findings, summary, action plan, and conclusion.

Keywords: action research, functional linguistics, mathematics literacy, application-based assessment, student achievement, word problems

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LIST OF ABBREVIATIONS

CHAPTER 1

OVERVIEW OF THE DISSERTATION IN PRACTICE

Introduction

Today's high-stakes, test-driven education system in the United States places enormous value on a student's arrival at correct answers to complex mathematical equations without regard for the student's conceptual understanding or application of mathematical models. This under-emphasis on conceptual understanding and application leads many educators towards prescribing one-size-fits-all, step-by-step lessons to solve equation after equation resulting in students who, given cookie-cutter problems, robotically churn out cookie-cutter answers. But, when equations turn into word problems, these same students do not know how to proceed and, in turn, meet with failure on assessments requiring application.

> If teachers do not make the connection between classroom instruction and application, it will be difficult for children to independently transfer information to long-term knowledge. Children must value their learning to internalize it. It is not sufficient, in today's society, for a child to only be able to repeat procedures. We need citizens with a depth of understanding that allows them to apply their knowledge in a variety of ways. (Fleming-Amos, 2007, p. 70)

Statement of the Problem

As a math teacher at Burdine High School (BHS) in South Carolina, the teacher-researcher has examined test data from the 2014-2015 school year. BHS's success rate on the South Carolina Algebra I End of Course (EOC) Exam was 93.7% in 2015; however, students at BHS underperformed in applied mathematics on the ACT's WorkKeys Exam with only 57.3% earning a silver, gold, or platinum certificate in the same year (Noel, 2015). There is an apparent disparity between student achievement on the Algebra I EOC and on application heavy assessments such as the WorkKeys exam. In fact, the teacher-researcher has experienced this struggle in transitioning students from finding solutions to algebraic problems to applying algebraic skills to real-world scenarios first hand within the classroom. Thus, the following Problem of Practice (PoP) has been identified: BHS students are not adequately prepared to apply algebra skills in authentic application-based scenarios.

Functional Linguistics of Mathematics: A Potential Remedy?

Because students are often unfamiliar with the language of mathematics, they often lack the ability to apply algebraic knowledge to novel situations (Huang, Normandia, & Greer, 2005). And, because mathematics originates in the need for communicating problems and as a language for problem solving, a linguistics approach to mathematics instruction may remedy this applied mathematics shortcoming. Mathematics instruction lacking an emphasis on literacy and linguistics denies students the opportunities to connect their learning of mathematical skills to the underlying concepts of the specific content of a lesson (Huang et al., 2005).

A *functional linguistics* mathematics instructional approach, however, gives students an opportunity to develop their mathematical problem-solving skills by teaching mathematics as a language for solving problems while emphasizing content specific vocabulary, phrasing, and symbolic representations (Bruun, Diaz, & Dykes, 2015). In fact, functional linguistics instruction may improve a student's ability to successfully complete application-based mathematics tasks by improving student knowledge of mathematics specific vocabulary, reading comprehension, and fluency in mathematical expressions (Kan & Bulut, 2015).

Functional Linguistics of Mathematics as a Vehicle for Social Justice

Furthermore, functional linguistics may act to bridge the achievement gap seen among underprivileged students in mathematics courses and on mathematics assessments. Marginalized students are frequently ill-equipped and ill-prepared for adult life requiring financial literacy and problem-solving skills (de Freitas & Zolkower, 2009). These students often lack quantitative literacy and come to mathematics lacking confidence (Larnell, Bullock, & Jett, 2016).

Whereas neutral and traditional mathematics instruction, by means of passivity, functions as an oppressor of marginalized people (Bond & Chernoff, 2015), this Dissertation in Practice (DiP) seeks to utilize functional linguistics in mathematics instruction to build quantitative literacy and academic confidence while promoting a citizenry prepared for tackling social issues, making wise financial decisions, and thinking critically about quantitative problems and information (Weist, Higgins, & Frost, 2007) thereby fostering social mobility and equity.

The Functional Linguistics of Mathematics Instruction Model

The Functional Linguistics of Mathematics Instruction (FLMI) model is an instructional model developed by the teacher-researcher based on the Functional Linguistics Framework (FLF) presented by Huang, Normandia, & Greer (2005) in their article, “Communicating Mathematically: Comparison of Knowledge Structures in Teacher and Student Discourse in a Secondary Math Classroom”. Additionally, the FLMI model utilizes Freire’s (2013) problem-posing pedagogy to frame an instructional unit. That is, one instructional unit in the FLMI model begins with an overarching thematic investigation which poses a problem that drives daily lessons within the unit and ends with an authentic assessment which revisits the overarching thematic investigation and requires students to both solve the posed problem and communicate the solution and problem-solving process.

Daily mathematics skill-based instruction is bookended with functional linguistics instruction and socio-mathematical assessment in the FLMI model. Each lesson in the FLMI model begins with linguistics (verbal and symbolic) instruction, as in the FLF. Secondly, mathematics skill instruction is delivered in any fashion that already exists within the teacher’s repertoire. The FLMI model’s third and final daily component, socio-mathematical learning activity/assessment, is derived from the FLF as well and is an application-based activity/assessment involving communication with others regarding the problem-solving process. The FLMI model differs from traditional classroom instruction in its initial and final daily instructional components as well as its overarching thematic investigation.

In addition to its overarching thematic investigation, daily linguistics instruction, and socio-mathematical components, the FLMI model emphasizes lexical bundling that promotes problem solving strategies and techniques while steering students away from following prescriptive teacher directed procedures. Figure 1.1 illustrates the FLMI model's organization.

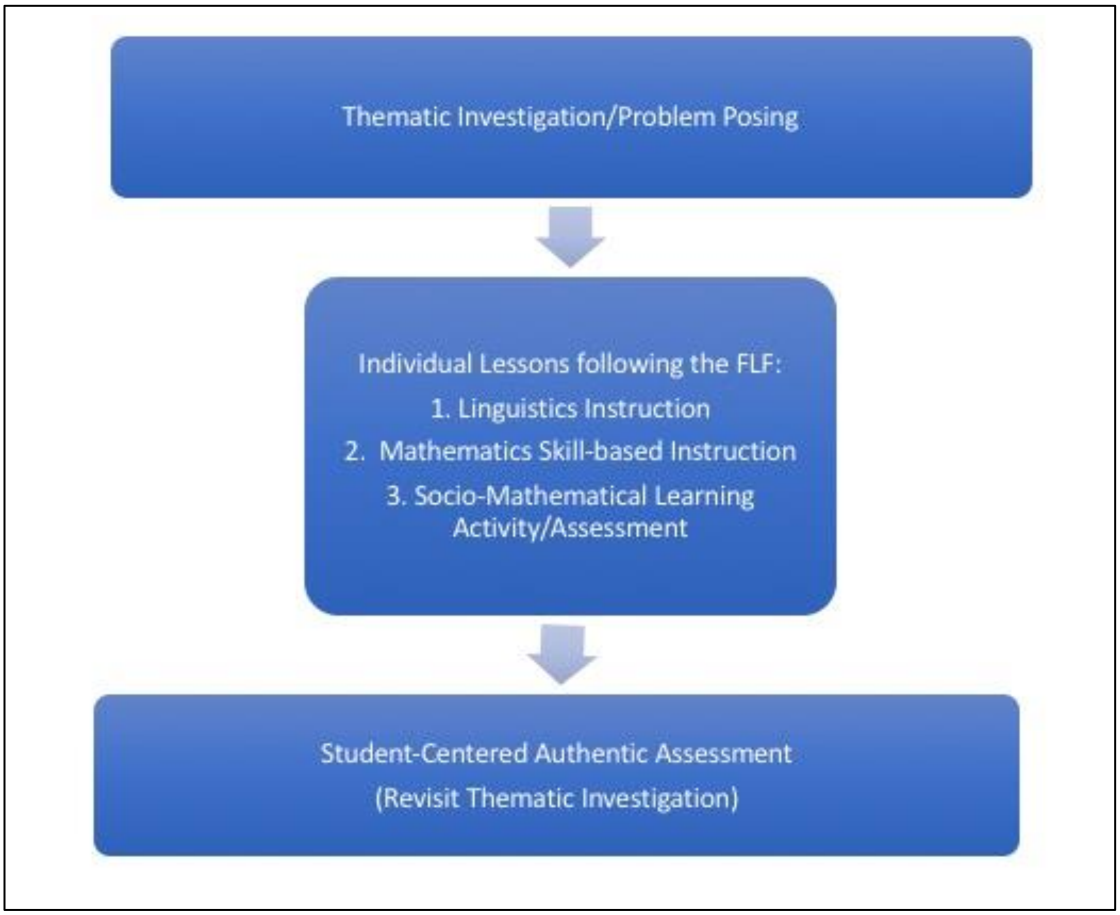

Figure 1.1: Summary of One Instructional Unit taught According to the FLMI Model

A sample thematic investigation and the investigation used in this study follows and can been seen in its entirety in Appendix G:

> Mrs. Burnett has been asked to photograph the 2020 Olympic Diving team. She knows that the function $h(t) = -5t^2 + 10t + 3$ represents the height of a diver above the water (in meters), t seconds after the diver leaves the springboard. (You know because she's super smart and all.) So what's the problem? Well, Mrs. Burnett is kind of clumsy and fell coming into the school this morning to teach all of her fabulous students. Unfortunately, she suffered a little brain damage because of her fall. She needs to figure a few things out before she meets up with the team to do their photo shoot but her brain is not quite functioning like it used to…stupid speed bump.

According to the FLMI model, students are first exposed to the thematic investigation before receiving any instruction. Over the course of the following lessons, students will receive vital instruction in solving the investigation. These lessons follow according to the FLMI model's protocol for individual lessons. A sample daily lesson may proceed as follows:

1. Linguistics Instruction
    a. Vocabulary list including lexical bundles
    b. Teacher questioning and class discussion promoting the use of new vocabulary and lexical bundles
    c. Teacher modeling the use of functional linguistics to solve a basic arithmetic word problem involving new vocabulary and utilizing multiple representations

2. Mathematics Skill-Based Instruction
    a. Direct instruction or lecture with notes guide
    b. Teacher modeling of newly taught skill and drill problems
    c. Guided practice
    d. Independent practice
3. Socio Mathematical Assessment
    a. Group collaboration to solve an application based problem that involves both the functional linguistics and new mathematical skills learned in the lesson
    b. Presentation to peers of problem solving process and communication of solution

It is important to note that both the sample thematic investigation and the sample lesson provided above are samples and that variations of these are only limited to the teacher's professional repertoire. Further discussion of the FLMI model, content literacy, functional linguistics, lexical bundling, socio-mathematical assessments, and the FLMI model as it addresses social justice issues follows in Chapter Two: "Review of Related Literature."

Methodology

The following paragraphs outline the purpose of the study, research question, action research methodology, and a summary of the findings. Further details regarding the mixed-methods data collection design and data analysis methods employed are outlined in Chapter Three: "Methodology."

Summary of the Purpose of the Research

The primary purpose of the current action research project is to evaluate the FLMI model's effect on student perceptions of and performance on application-based assessments in a quadratics unit in Algebra 2 at BHS. In utilizing the FLF as a basis for the FLMI model, the teacher-researcher aims to improve student performance and increase student confidence by enabling students to interact with mathematical concepts beyond merely deriving answers via prescriptive processes. Secondarily, the teacher-researcher seeks to gain an understanding of pedagogical practices that will best prepare students for application-based assessments and improve students' confidence when tasked with transferring algebraic knowledge to novel problems. In line with action research methodologies (Mertler, 2014), the teacher-researcher describes and reflects on her teaching practices and develops an action plan for moving forward in teaching her Algebra 2 classes at BHS.

Research Question

This DiP seeks to address the following research question (RQ): To what extent does the FLMI model affect student perceptions of and performance on application-based assessments of quadratics in Algebra 2 courses at the secondary level?

Action Research Methodology

In *Experience and Education*, John Dewey (1938) calls for educators to depart from the pedagogies of traditional education and turn towards authentic classroom experiences to guide the teaching process. In short, he suggests that students learn best when presented with experiences that engage them in the learning process. The notion of experience guiding education reaches well beyond the student learning process and is, in fact, the guiding principle behind action research. That is, educators operate within their own classroom experiences to identify and attempt to solve problems they encounter (Mertler, 2014). Action research takes a hands-on approach to addressing these problems of practice through reflective research techniques (Mills, 2007).

Action research, or teacher inquiry, is done by the teacher for the benefit of the teacher and her students. It is not intended for generalization to the larger population and is, therefore, less rigid than traditional research (Dana & Yendol-Hoppey, 2014). "Action research allows teachers to study their own classrooms – for example, their own instructional methods, their own students, and their own assessments – in order to better understand them and to be able to improve their quality or effectiveness" (Mertler, 2014, p. 4). Action research is research done in practice to improve practice.

As the teacher-researcher examines the effectiveness of the FLMI model in her Algebra 2 instruction to improve the learning experiences and outcomes of those students under her instruction, action research is appropriate for doing so. The teacher-researcher employed action research using a mixed-methods design utilizing descriptive statistical analysis to examine the effectiveness of the FLMI and answer the RQ within the context of her classroom and current students. Because action research does not rely on traditional research techniques such as experimentation, randomization, and control which are difficult and potentially unethical to obtain in an educational setting, it is better suited for this study.

Summary of the Findings

The findings of this study show a positive gain in both student achievement on application-based assessments and in student perceptions regarding application of algebraic skills to real-world problems. An average of nearly 50% gain from pre- to post-test scores among 23 student participants and qualitative survey result findings show that the FLMI model has potential to improve the performance of Algebra 2 students at BHS on application-based assessments. Chapter Four: "Findings, Discoveries, Reflections, and Analyses" further discusses these findings.

Assumptions, Limitations, and Delimitations

Assumptions

This DiP is dependent upon a variety of assumptions regarding the Algebra 2 curriculum, BHS, and the students enrolled in the teacher-researcher's Algebra 2 course at the time of the study. The Algebra 2 curriculum at BHS adheres to the South Carolina College- and Career-Ready Standards for Mathematics. This study specifically aims to address standard A2.AREI.4 which reads "solve mathematical and real-world problems involving quadratic equations in one variable" (South Carolina Department of Education, 2015, p. 115). It is assumed and highly likely that this standard will remain in the Algebra 2 curriculum at BHS and that the South Carolina College- and Career-Ready Standards for Mathematics will not be revised to remove this standard during the course of this study and thereafter. While South Carolina has made adjustments to the Algebra 2 curriculum standards in the past, the application of quadratic equations to real-world problems has not been excluded at any point in the duration of the teacher-researcher's career.

Additionally, it is assumed and highly likely that the teacher-researcher will retain her role as the primary Algebra 2 instructor at BHS during the course of the study and thereafter. During the teacher-researcher's career, the teacher-researcher has been responsible for teaching Algebra 2 every semester of every year. Furthermore, as the teacher-researcher is granted the opportunity to select those classes she prefers to teach, there is no reason, at present, to believe that the teacher-researcher will not teach Algebra 2 in subsequent years.

Finally, it is assumed and highly likely that the students enrolled in the teacher-researcher's Algebra 2 course at the time of data collection are representative of the teacher-researcher's future Algebra 2 students and that their perceptions and performance will be indicative of their knowledge and skill at the time of assessment. Students are enrolled in Algebra 2 after completing prerequisites for the course. This ensures that all students taking Algebra 2 have a similar base of knowledge in mathematics curriculum. Furthermore, data collection was conducted under the teacher-researcher's supervision and confidentiality and anonymity assisted in ensuring an accurate reflection of their perceptions and knowledge at the time of data collection.

Limitations

The results of this study are confounded by variables outside of the teacher-researcher's control. These include limitations regarding the sampling technique, sample size, duration of the study, and exceptionalities of students included in the study. Ethical considerations in conducting educational research often call for the researcher to use convenience sampling. Thus, inferential statistics cannot be trusted and results of the study cannot be generalized. However, as this DiP reflects action research as described by Mertler (2014), the teacher-researcher does not intend to generalize the results of the study to the broader field – that is, to different teachers, schools, or subjects. Instead the results of this study will guide and direct the teacher-researcher's future Algebra 2 instruction.

Additionally, the DiP is limited in regards to the duration of the study. Due to the time frame allotted for completion of the DiP, the teacher-researcher was constrained to an inadequate period for data collection for assessing the value of the FLMI model as a method for improving students' confidence and skills in transferring algebraic procedures to real-world problems over the course of a full class term. For this reason, the teacher-researcher selected one unit of study, solving quadratic equations, in which data was collected. The results of the DiP, therefore, can only be applied to instruction in solving quadratic equations. Further research will be required to determine the long-term effectiveness of the FLMI model. The teacher-researcher intends to, upon completion of the DiP, study the effect of the FLMI model over an entire Algebra 2 course.

Lastly, the DiP is limited in regards to exceptionalities of students included in the study. As BHS is highly diverse, students in the teacher-researcher's Algebra 2 courses possess many exceptionalities. Several participants in the study qualify for special services, have behavioral or academic accommodation plans, or receive accommodations as English Language Learners. Furthermore, as the Algebra 2 students involved in the study are lower-performing students, as evidenced by the teacher-researcher's experiences during previous units within the course of the term, participants possess gaps in mathematical knowledge or lack number sense skills. Lastly, the students participating in this study represent the inaugural class of BHS's Careers Academy. These students have been identified and special attention is given in determining variations within the findings for those students enrolled in the Careers Academy. The teacher-researcher gathered information concerning the exceptionalities of the students prior to implementing the FLMI model and will disclose this information in the communication of the results of the DiP provided in Chapter Three: "Methodology."

Delimitations (Scope)

This DiP describes Algebra 2 students in a diverse South Carolina high school. The results of this study represent students of a large variety of race, ethnicity, gender, and class. The results of this study, while not generalizable due to the nature of action research (Mertler, 2014), represent the effects of the FLMI model on a diverse student population of students in Algebra 2 in South Carolina studying quadratics. The scope of this study is limited to these qualifiers.

Conclusion

This DiP specifically outlines an action research study that addresses the need for a change in instructional practices in an Algebra 2 class at BHS to improve students' abilities to transfer mathematical skill to real world applications. The FLMI model – a teacher-researcher created model informed by research in functional linguistics, problem-posing pedagogy, socio-mathematics, and lexical bundling – is designed in an effort to improve student confidence with and performance in transferring mathematical skills to real-world application-based tasks. This model has been implemented in the quadratics unit of an Algebra 2 course at BHS and the effectiveness of this model is evaluated in this DiP.

Glossary

Functional Linguistics: The rules and guidelines (including vocabulary and syntax) of a language specific to the discipline the language is used to communicate; "academic language, including the grammar, vocabulary, and distinctive discourse structure of the text that typically occur in [specific] content areas" (Schulze, 2015, p. 109)

Grammar (as understood in mathematics): The use and arrangement of numbers and symbols in mathematical communications

Vocabulary (as understood in mathematics): The terms, phrases, graphical representations and syntax used in mathematical communications

Discourse (as understood in mathematics): Dialogue (oral or written) as it pertains to mathematical concepts and ideas as well as to the problem-solving process.

Functional Linguistics of Mathematics Instruction (FLMI) Model: A teacher-researcher created teaching model embedded within an authentic thematic investigation involving teaching the functional linguistics of mathematics prior to teaching procedural skills and utilizing socio-mathematics activities and assessments to solidify and demonstrate learning.

Mathematics Literacy (or Quantitative Literacy): "specialized literacy practices of [mathematics]" (Moje, 2015, p. 256); fluency in reading, writing, and speaking the language of mathematics using symbolic, graphic, algebraic, numeric, tabular, and verbal representations

Lexical Bundling: The grouping of words that frequently recur within a text or transcript that, when strung together, carry a specific meaning aside from the meanings of the individual words; "the highest frequency word strings in corpora" (Thomson, 2016, p. 2)

Socio-mathematical Activities and Assessments: The solving and communication of authentic mathematical problems, processes, and solutions within a social network, either face to face or through technology, through discussion or written explanation

DiP Overview

Chapter One: "Overview of the Dissertation in Practice" has discussed the PoP, RQ, purpose statement, and a framework for an action research study of the impact of the FLMI model at BHS. Chapter Two: "Review of Related Literature" further discusses related literature and theories of the FLF and FLMI model as well as mathematics literacy instruction and the social justice issues surrounding mathematics literacy. These epistemologies and theories are connected to the pedagogical practices used in the present action research study. Chapter Three: "Methodology" further details and delineates the data collection, data recording/coding, and data analysis processes for this study. Chapter Four: "Findings, Discoveries, Reflections, and Analyses" presents and discusses the data collected to describe the effects of the FLMI model while relating these results to the established PoP in order to answer the RQ. Chapter Four serves to examine and evaluate the merit of the FLMI model as an instructional tool in Algebra 2 courses at BHS. Chapter Five: "Conclusions and Suggestions for Future Research" describes the teacher-researcher's role as a curriculum leader, presents an action plan for moving forward with instructional planning, and outlines recommendations for future research.

CHAPTER 2

REVIEW OF RELATED LITERATURE

Introduction

BHS students lack application skills requiring transfer of mathematical procedural knowledge to authentic problem-based scenarios as is evident in reviewing data from the Algebra 1 EOC Exam and the ACT WorkKeys program (Noel, 2015). Additionally, the teacher-researcher acknowledges a difficulty in moving students from finding solutions to algebraic problems to applying algebraic procedures to real-world scenarios. As such, the teacher-researcher has created the FLMI model as a potential solution to this applied mathematics shortcoming.

Overview of the FLMI Model

The FLMI model seeks to address the instructional needs of students at BHS by challenging essentialist atomized mathematics pedagogy. Furthermore, it lessens the emphasis on skill and drill procedural methods of teaching mathematics while seeking to hone problem-solving skills. A unit of instruction following the FLMI model begins and ends with an authentic thematic investigation aligned with Freire's (2013) problem posing pedagogy. Lessons designed in accordance with the FLMI model emphasize mathematics as a language designed for solving problems and provide students and teachers opportunities for dialogue. The FLMI model is informed by Huang, Normandia, and Greer's (2005) activity model for teaching mathematics literacy. Lessons designed in accordance with the FLMI model consist of the following three components.

1. Instruction in Mathematics Lexicon/Vocabulary
2. Instruction in Mathematical Operation
3. Socio-mathematical Assessment

Purpose of the Research

The purpose of the current DiP is to evaluate the impact of the FLMI model on student perception of and performance on application-based assessments. The teacher-researcher aims to enable students to transfer equation solving skills to mathematical modeling problems. Additionally, the teacher-researcher seeks to identify instructional techniques that will best prepare students for application-based assessments. Finally, the teacher-researcher utilized the findings of the study to develop an action plan for moving forward in teaching her Algebra 2 classes at BHS.

Research Question

To what extent does the FLMI model affect student perception of and performance on application-based assessments of Quadratics in Algebra 2 courses at the secondary level?

Importance of the Literature Review

While the application of action research is local and its results cannot be generalized (Mertler, 2014), it must still be rooted in previous research in the field. This review of literature is necessary in establishing the premise for the DiP. Mertler (2014) describes the review of literature as a reflective process that the teacher-researcher engages in to allow the teacher-researcher to connect the study to others in the field and asserts that the literature review provides multiple perspectives and insights for future research. Educators are not isolated; educators of generations past and present have paved the way and documented much of their experience and findings. These findings are presented in a wealth of literature. Wise teachers engage in collecting valuable insight on their practice through constant reviews of this literature. Dana and Yendol-Hoppey (2014) describe this process saying

> No one teaches or inquires in a vacuum. When we engage in the act of teaching, we are situated within a context (our particular classroom, grade, level, school, district, state, country), and our context mediates much of what we do and understand as teachers. Similarly, when teachers inquire, their work is situated within a large, rich, preexisting knowledge base that is captured in such things as books, journal articles, newspaper articles, conference papers, and websites. Looking at this preexisting knowledge base on teaching informs your study. (p. 86)

Organization and Methodology of the Literature Review

This review of related literature underpins and justifies the DiP by examining the underlying causes of the PoP and provides a rationale for the FLMI model as a shift in pedagogy that attempts to remediate learners' inadequacies in transfer of mathematical skill. Additionally, and of most importance, the review of literature provides a theoretical framework for the FLMI model and its implementation. The framework for the FLMI model is subdivided as follows: thematic investigations and problem posing pedagogy, flexibility within the problem-solving process, socio-mathematical assessment, mathematics literacy instruction, functional linguistics, lexical bundling, and the FLMI model as a means for social justice. This literature review informs and grounds the research presented in the DiP using both primary and secondary sources in curriculum theory and mathematics pedagogy. It aims to provide a scholarly basis for the FLMI model while informing the direction the research takes.

Underlying Causes of the PoP

Decades of public education reform in the United States have placed heavy emphasis on standardization of curriculum. During the 1950's "concerns arose that the curriculum lacked academic rigor and, as a consequence, academically talented young people were failing to realize their potential" (Flinders & Thornton, 2013, p. 55). In fact, concern grew out of the Second World War that American pedagogy was failing to develop a proper understanding of mathematics among students. The Soviet Union's launch of Sputnik only further instilled an urgency for curriculum reform (Schiro, 2013). These rising concerns spurred standardization of curriculum and a push for standardized high-stakes accountability measures which would inevitably result in the atomization of mathematics curriculum into small skill and drill procedural bits of knowledge and steer mathematics curriculum away from conceptual holistic knowledge.

Mathematics education has suffered the effects of the standardization of mathematics instruction. As Good and Grouws (1987) observe, mathematics pedagogy has shifted to place "too much attention to procedural detail and too little to understanding mathematical concepts…[and] little instruction in problem solving" (p. 779). Furthermore, Scorza, Mirra, and Morrell (2013) submit that "an era of hyperstandardization and ‘racing to the top’… with its emphasis on accountability has particularly detrimental impacts” (p. 16).

While many popular curriculum theorists promote an essentialist or perennialist curriculum paradigm, such a pedagogical approach further encourages atomized instruction. Adler’s (2013) *The Paideia Proposal*, for instance, argues that there should be no choice in the curriculum (or specialization of curriculum) provided to children in the United States and, therefore, promotes standardization of curriculum. However, Noddings (2013) criticizes Adler’s (2013) proposed curriculum by arguing that

> When children must all study the same material and strive to meet the same standards, it becomes infinitely easier to sort and grade them like so many apples on a conveyor belt…But the beautiful truth is that when we take all of the valuable aspects of life into consideration and when we respect all of our children’s legitimate interests in our educational planning, it becomes *easier* to teach the basic skills. (pp. 190 – 194)

The PoP of the current DiP is rooted in *Social Efficiency*. *Social Efficiency* ideologists Bobbitt (2013), Tyler (2013), and Popham (2013) call for a focus on the development of objectives which emphasizes the child’s role as a future member of society and his/her place in industry. *Social Efficiency* curriculum is reflected in recent federal legislation such as the No Child Left Behind Act and the Race to the Top Fund (Schiro, 2013). Schiro (2013) describes Bobbitt’s scientific method for developing curriculum as an atomization of academic disciplines.

Social Efficiency’s aim of standardizing curriculum to serve the state resulted in standardized assessments. In a metasynthesis of the effects of high-stakes testing on curriculum, Au (2013) found a dominant effect of "narrowing/contraction of curriculum to align with high-stakes tests" (p. 239). Of the 49 qualitative studies examined, the prevailing themes were "contracting curricular content, fragmentation of the structure of knowledge, and increasing teacher-centered pedagogy in response to high-stakes testing" (p. 245). The outcome of the pedagogical changes in the post-standardization era of curriculum is that content is "often learned only within the context of the tests themselves" (p. 245). This raises concerns that students are, therefore, inadequately prepared to transfer knowledge.

> In transforming subjects into something all students need to be able to demonstrate on a test, do we inadvertently lower performance standards, weaken existing professional accountability systems, or lose knowledge outside the core altogether? The knowledge that standards are supposed to measure – to ensure that the next generation receives it intact – is being altered by the act of measuring itself. (Sisken, 2013, p. 277)

Social Efficiency's focus on objectives and standardization has had negative repercussions in the ways of application and transfer of mathematical knowledge. In fact, Au (2013) found that because of high-stakes testing "math and science were increasingly being taught as a collection of procedures and facts, as opposed to being taught as conceptual, thematic, and higher order mathematic and scientific thinking" (p. 240).

Noddings (2013) argues against social efficiency centered aims in regards to mathematics curriculum saying…

> Mathematics can be taught so as to require deep reflective and intuitive thinking or it can be taught as a mindless bag of tricks. It is not the subjects offered that

> make a curriculum properly a part of education but how those subjects are taught, how they connect to the personal interests and talents of the students who study them, and how skillfully they are laid out against the whole continuum of human experience. (p. 193)

Scott (2004) outlines three ways in which such hyperstandardization has presented noteworthy challenges to education. First, he argues that it causes students to disengage from content that they determine is not important to their performance on high-stakes tests. Second, teachers have reduced their pedagogy to skill and drill test-prep exercises. And, last, students are deprived the opportunities to apply knowledge through investigation and inquiry. However,

> In an era of globalization students must possess multivalent skills in order to effectively adjust and adapt to the multidimensional challenges of the twenty first century. As such, students must acquire the capability to visualize alternative futures, solve problems that have unpredictable consequences, utilize sophisticated technology in their personal and professional lives, engage in shared decision-making in a multicultural and/or multinational environment, and learn to engage in calculated risk-taking behavior. (Scott, 2004, p. 19)

The atomization of curriculum, in regards to mathematics, has created an environment for training students to robotically follow procedures for solving mindless equations while failing to prepare students to think critically so as to apply procedural skills to novel and complex situations.

Framework for the FLMI Model

The FLMI model is informed by research findings related to thematic investigations and problem posing pedagogy, flexibility within the problem-solving process, socio-mathematical assessment, mathematics literacy instruction, functional linguistics, lexical bundling, and social justice of mathematics literacy.

Thematic Investigations and Problem Posing Pedagogy

The thematic investigations used in the FLMI model are inspired by Freire's (2013) problem posing pedagogical technique. Freire (2013), seeking to use education as a means for social justice and liberation of the oppressed, believed that by engaging students in dialogue and utilizing thematic investigations, students could be successfully prepared for integration in society.

Dewey (2013), in *My Pedagogic Creed*, establishes five principle beliefs that ground the thematic investigations used in the FLMI. First, the student is a member of society who learns by participation in society. Second, Dewey (2013) asserts that the school's primary function is as a social organization which mimics society at large. It must do so in a simplified fashion that allows students to gradually learn to become citizens of society at large. The teacher's role in this community is as a facilitator of these learning experiences. Third, the curriculum should be grounded in social life and prepare students for adulthood in society. Academic disciplines are secondary and serve to support learning about social life. Practical life experiences serve as a springboard into the study of advanced academic subjects. It is "desirable that the child's introduction into the more formal subjects of the curriculum be through the medium of these constructive activities" (p. 37). Fourth, teaching should stem from student interests, experiences, and curiosities. Repressing student interests results in the stifling of learning. Last, Dewey (2013) posits that education is the vehicle for social reform. "Through education society can…shape itself with definiteness and economy in the direction in which it wishes to move" (p. 39).

Thematic investigations provide opportunities for students to apply mathematics knowledge, experience new mathematical applications, hone problem-solving skills, endure in the problem-solving process, and, because they are often completed in groups, boost communication skills. Additionally, the use of investigations for assessment gives teachers helpful insight concerning the thought processes that students use in solving the problems as well as any gaps in knowledge that may need to be addressed or enrichment that may be helpful for students in making sense of broader mathematical connections (Greenes, 1996).

Furthermore, thematic investigations may increase students' mathematic literacy skills. Chauvin & Theodore (2015) conclude that such authentic tasks

> support students' content literacy because they show students that the content and literacy are relevant to their lives. They also can increase students' motivation and increase their academic vocabularies…researchers find that authentic tasks are worthwhile because they will likely lead to higher student engagement and more meaningful learning. (p. 5)

Flexibility within the Problem-Solving Process

Through thematic investigations, or problem-posing instruction, students are free to creatively and critically solve problems. Mathematics literacy enables students freely to navigate, communicate, and manipulate problems and solution processes using a variety of linguistic methods. It is necessary, then, that teachers implementing the FLMI model allow for a variety of solution approaches and presentations as students work within the framework of instruction.

Abdullah (2013) writes

> According to Freire, for the implementation of the problem posing education, it is necessary to abandon the thoughts that educators hold absolute knowledge. In this model, the educator should be ready for a dialogue based relation…the educator must act in such a way to enable action and thinking to be in interaction with each other…Freire proposes dialog in this model of education, in which the teacher and the learner jointly undertake the act of knowing. Freire regards dialog as the basic item in the knowledge structure. So the classrooms designed in accordance with this model of education will become the meeting places where information is researched. (p. 104)

Hlebowitsh (2013) promotes the embracing of "the ambiguous nature of the classroom – to accept the unanticipated question or strange tangent as they put it, that emerges from the educational situation" (p. 227). This call for educators to behave in a pedagogically opportunistic manner and take advantage of the teaching moments that occur by allowing for flexibility within the lesson plans of scientific curriculum. The FLMI model is designed to allow for such flexibility. As teachers implement the FLMI model, they must allow students flexibility in the thought process and mathematical procedures used to arrive at solutions. Failing to do so further encourages robotic commitment to prescriptive processes. Hlebowitsh (2013) argues "teaching is indeed guided by goals, but it also produces its own goals from within" (p. 227). Such flexibility within the canon and practice of teaching allows for aha moments and opportunities for true reflection on the part of the learner that will indeed prepare him/her for dealing with societal problems in the future. The FLMI model is designed to allow for such flexibilities within its framework.

Socio-mathematical Assessments

Vygotsky (1981) asserts "all higher mental functions are internalized social relationships" (p. 164). Therefore, to hone problem-solving skills, teachers must shape learning activities that promote and elicit social activity. "Vygotskyan theory, or social constructivism as we might call its application to education, thus calls for an approach to learning and teaching that is both exploratory and collaborative" (Wells, 2000, p. 58). Therefore, socio-mathematical assessments in the FLMI model adhere to these two specific requirements: exploration (or application-based tasks) and collaboration (or communicative interactions amongst students). These aspects of the socio-mathematical assessment component are critical. Each lesson in the FLMI model is culminated with a socio-mathematical assessment that must be an application-based task that connects mathematics with the world beyond mathematics and is designed to elicit communicative interactions amongst students.

Application-based tasks. The FLMI model addresses the need to move from *social efficiency's* atomization towards a connected and application-based curriculum. The socio-mathematical assessments used in the FLMI model are designed to reflect Doll's (2013) four R's. Doll (2013) having been taught the three r's – reading, writing, and arithmetic – as a child, argues that four r's – "Richness, Recursion, Relations, and

Rigor" (p. 216) - are necessary for preparing children to thrive in modern society. Richness equates to depth of exploration of the curriculum. Recursion refers to the looped-nature of well-designed curriculum – that is, each new concept loops back to the previous and builds on it to prepare for the next. Doll's (2013) discussion of relations includes both how concepts within the curriculum relate to each other and how the curriculum relates to societal culture. And, rigor, in this discussion, is a progression from "scholastic logic, scientific observation, and mathematical precision" (p. 221) towards seeking alternatives, patterns, connections, and interpretations. The FLMI model seeks to incorporate each of Doll's four R's within its instructional framework and, particularly, in its application of socio-mathematical assessments.

The socio-mathematical assessments used in the FLMI model serve as formative assessments through which learning is evaluated, but also through which learning continues to take place. These assessments should "present curiosity provoking situations, problems and questions that are intriguing and captivate students' interest and attention…[and should be] interdisciplinary, requiring students to apply concepts from the various areas of mathematics, and, for some problems, from other disciplines as well" (Greenes, 1996, p. 37).

Communicative interactions amongst students. Aligned with Vygotsky's (1981) dialogic pedagogy, socio-mathematical assessments are designed to elicit learning in a social setting. "Students' learning of mathematics in teaching processes is enclosed in language and communication" (Steinbring, 2015, p. 282). As Friere's (2013) problem posing pedagogy involves dialogue within the social construct of the classroom to solve problems and communicate mathematical thinking and as Vygotsky (1981) insists that higher cognition is elicited in a social context, it is important to provide learning opportunities for students that promote mathematical communication. Such communicative interactions naturally promote "Richness, Recursion, Relations, and Rigor" (Doll, 2013, p. 216). Thus, socio-mathematical assessment serves as the culminating activity for each lesson taught following the FLMI model.

The basis of socio-mathematics is that students draw the connections between social activity and mathematical procedures and applications through communication with others. This involves both the connection of mathematics to social interactions within the classroom and to society beyond the classroom. Sleeter and Stillman (2013) cite research findings that promote the importance of contextualization of content and the use of "language, thinking, values, culture and identity" (p. 255) to further develop the understanding of core concepts. It is through interacting with the student's environment and the broader society that contextualization can take place.

Students comprehend and retain more information when required to communicate the problem-solving process with others (Fleming-Amos, 2007). "By articulating the principles, concepts and rationale behind the steps of a particular problem solution, students have the opportunity to reinforce and deepen their understanding of higher-level knowledge structures in mathematics content" (Huang, Normandia, & Greer, 2005, p. 45). Socio-mathematical assessments require that students not only solve problems, but communicate both the meaning of their solutions and the process by which they came to their solutions to a social network, either face-to-face or through technology, by discussing or writing about the assessment. In keeping with Freire's (2013) emphasis on dialogue-based pedagogy and Vygotsky's (1981) "social foundations of cognition" (p.

145), socio-mathematics relies heavily on communication of mathematical concepts between students and between teacher and student. "Communication builds a foundation for students to make natural yet significant cognitive connections" (Fleming-Amos, 2007, p. 70). When students communicate mathematically, they are thinking mathematically and, therefore, developing conceptual understandings that will enlighten future problem solving. Furthermore, Landers (2013) indicates that such interaction with others causes students to take ownership because they are held accountable by their peers for completing the tasks.

Pace & Ortiz (2016) point to student collaboration and mathematical literacy strategies that involved having students communicating mathematical processes (i.e. socio-mathematical activities) as the significant change in instruction that allowed them to claim that "students were making connections" (p. 499). Specifically, they cite conversations with partners as the primary factor in improved student performance.

Such socio-mathematics are not solely appropriate at higher levels of mathematics. Students can begin the mathematical communication necessary in developing deeper conceptual understanding at any age and level. However, socio mathematics does not necessarily come naturally for students or teachers.

> Instructional design in math education would be best served by systematically integrating math thinking and math talking at all levels of knowledge structure…teaching strategies should promote such discourse by students. To achieve this goal, teachers need to play the role of both a mathematician and a mentor – to do math but also to 'talk' math as a way to model for the students the way they should talk math. (Huang, et al., 2005, p. 48)

Mathematics Literacy Instruction

Meanwhile, mathematical communication requires the use of a secondary language – one that is not native; it requires the use of the language of mathematics. Thus, mathematics instruction is language instruction. To do math requires knowing and understanding this language; students must become mathematics (or quantitatively) literate.

The need for mathematics literacy. Content specific literacy skills are becoming increasingly more necessary in developing conceptual understanding of highly technical fields such as mathematics and science (Shanahan & Shanahan, 2008). And, according to Fang & Schleppegrell (2010), over eight million fourth- through twelfth-grade students are underprepared to tackle disciplinary texts and are in need of disciplinary literacy remediation. Shanahan and Shanahan (2008) report that data suggest that literacy skills among adolescents have weakened despite an increased call for content literacy and a marked emphasis on content literacy instruction over recent decades. Certainly, basic literacy instruction could be expanded to meet these demands, but literacy specialists suggest identifying and implementing content specific literacy instruction. Such content literacy instruction is shown to improve disciplinary comprehension.

Historical context. A pedagogical focus on literacy skills is not a new idea in education; in fact, literacy has been at the forefront of curricular discourse for over a century (Shanahan & Shanahan, 2008). In fact, it "has a long history in education, although purposes, perspectives, and approaches have changed over time" (Adams &

Pegg, 2012, p. 151). Throughout this history, two shifts in literacy instruction have occurred.

First, teaching literacy has shifted in regards to its purpose. Initially it was taught for the purpose of teaching children to read and extract information from content specific texts and to write content specific essays. This purpose was grounded in behaviorist theories as well as cognitive processing theory. Chauvin & Theodore (2015) distinguish this focus "on the ability to use reading and writing to learn the subject matter in a discipline" (p. 2) as *content-area literacy*. Over time, the purpose of literacy instruction shifted towards promoting "disciplinary discourses and content understanding" (Adams & Pegg, 2012, p. 152).

The second shift in literacy pedagogy involved a shift from "understanding literacy as a collection of general skills that can be applied to any discipline, to viewing literacy as an integral part of content learning within the discipline" (Adams & Pegg, 2012, p. 152). This shift focuses on discipline-learning as language-learning; i.e., to learn mathematics is to learn the language of mathematics. Chauvin & Theodore (2015) call this focus *disciplinary literacy*, i.e. "how reading and writing are used in the discipline being studied" (p. 2). It is important, then, to recognize that mathematics literacy, both as content-area literacy and as disciplinary literacy, is not only a tool for receiving knowledge through reading and listening, but also as a tool for communicating mathematically through writing and speaking (Moje, 2015).

Reading, writing, thinking, and talking mathematically. Kan & Bulut (2015) advise that, though mathematics is non-verbal, in many ways, reading comprehension skills remain necessary in understanding its content and argue that "one should know how to read and write in a language in which the symbolic language of mathematics is embedded" (p. 583). Bruun et al. (2015) conducted action research investigating the effects of journal writing, peer discussion, and graphic organizers on student achievement in mathematics and found that these methods had positive effects on student learning but also improved students' attitudes towards mathematics. Similarly, Dündar's (2015) research in mathematics literacy focuses on the impact of writing in mathematics class on student academic performance. She argues that writing in mathematics serves a multifaceted purpose in supporting student learning; writing increases retention, promotes self-organization and meta-cognition, develops positive attitudes towards math, communicates mathematical thoughts, establishes connections with previously learned material, and improves comprehension of mathematical concepts.

Multiple representations. Moxley and Taylor (2006) assert that mathematics is a *multiple symbol system* involving the use of multiple representations in communication of the discipline; in such a system, the development of literacy is developed holistically. Developing fluency with one representation, symbolic for instance, does not occur without developing fluency with all other types of representations simultaneously, i.e. graphically, verbally, etc (Moxley & Taylor, 2006). Leshem and Markovits (2013) maintain that by teaching mathematics as a language complete with vocabulary (content specific words and phrases), grammar (mathematical operational symbols used to create true mathematical statements), and interpretations (problem solving, estimations, connections to real world problems, and mathematical dialogue) students' understanding of the content will increase.

A holistic approach to mathematics literacy must be employed in preparing students to transfer mathematical skill. It is necessary to engage students in reading, writing, and thinking about math using multiple representations – words, symbols, tables, etc. "In addition to reading and writing words, mathematical literacy requires building meaning with symbols, contexts, graphs, diagrams, and other models as well as the ability to connect and translate among these and other mathematical modes of communication" (Thompson & Rubenstein, 2014, p. 105). Arcavi (2003) adds "the visual display of information enables us to 'see' the story, to envision some cause-effect relationships, and possibly to remember it vividly" (p. 218). Furthermore, Arcavi (2003) argues, mathematics literacy involving visual representation allows for conceptualization by using symbols and graphs. Thus, the literacy components of the FLMI model must include visual representation in addition to words and symbols. Students must be trained in the use of visual representations for mathematical communication in the same manner they are trained to utilize words and symbols.

Mathematics literacy and testing. Instruction in literacy strategies is necessary as students face application-based assessments. In a content analysis report on the Texas Assessment of Knowledge and Skills Test to examine the need for literacy skills when completing the mathematics problems, Matteson (2006) asserts that verbally represented problems "require the use of written language to understand, describe, analyze, explain, or reflect upon numerical, algebraic, or graphic representations" (p. 215). Additionally, she indicates the need for these literacy skills when decoding directions and symbols within numerically represented problems such as equations and expressions. However, she notes "mathematics educators must remain mindful that the ultimate goal of developing mathematical literacy is larger than raising mathematical assessment scores" (p. 228). Mathematical literacy is necessary as students become contributors to the global community as problem-solving adults.

Mathematics literacy and mathematical confidence. Mathematical literacy is essential for developing skills in applying mathematical knowledge to new contexts but also in developing mathematical confidence. Often students who are, in fact, mathematically literate express ignorance in the math classroom due to lack of confidence, and, as Maclellan (2012) states,

> Learners may possess relevant knowledge but be unaware of its appropriateness in novel situations. The transfer of quantitative ideas from one situation to a new and different one is a defining characteristic of [quantitative literacy], and supporting this development requires rich domain and pedagogical knowledge and self-regulation. (p. 1)

Limitations of mathematics literacy instruction. It is important to note, however, that proficiency in quantitative literacy rests on number sense and without number sense, learners may not benefit from mathematics literacy instruction. "Poorly developed Number Sense impedes the development of [quantitative literacy]" (Maclellan, 2012, p. 11) and teachers must identify and remediate those students who lack such reasoning. Number Sense must be promoted continuously alongside mathematics literacy for the positive effects of such instruction to be realized.

Literacy instruction and inquiry. Cervetti & Pearson (2012) submit that content literacy skills are best learned when used as "tools that enhance the quest for knowledge and expertise in a discipline" (p. 581) suggesting that literacy instruction take place during inquiry-based learning. "Language and literacy should support students' engagement in inquiry experiences" (p. 583). By embedding literacy instruction within inquiry, students are given the opportunity to practice both content literacy skills and engage with mathematical concepts.

One classroom example. Fleming-Amos's (2007) *Talking Mathematics* describes a third-grade classroom in which inter-student dialogue is used to encourage and assess higher order thinking skills as students complete a mathematics lesson. As students work in groups to solve an authentic inquiry task, the instructor can move about the room assessing students on a myriad of skills and the students can develop and build necessary problem solving skills. It is particularly of note, though, that "these observable results do not come easily. The teacher explicitly plans opportunities for listening, speaking, and writing about mathematics as a daily part of her instruction" (p.71). Whether reading, writing, thinking about, or discussing mathematical ideas, mathematics literacy is necessary in moving students from solving repetitive skill and drill type problems to conquering real-world applications of mathematics and therefore necessary in performing socio-mathematics tasks.

Functional Linguistics

"Because the vocabulary embodies the concepts to be learned, when we teach vocabulary, we teach the content" (Gillis, 2014, p. 286). Functional linguistics refer to the content specific vocabulary and syntax of a discipline and should be a necessary component of any mathematics curriculum. Halliday (2005) writes

> It [is] necessary to develop a clear sense of the overall architecture of language – or perhaps (since we need to keep both structure and process in focus) of

> language's city plan and traffic flow. This in turn demands a comprehensive and 'thick', or multidimensional, account of language as a system, in its context of culture, to which we may then relate our detailed microanalyses of instances of that language, in all their highly varied context of situation. Whatever the kind of texts, whether a poem, an exposition in science, or a student's narrative composition, when we come to explain why the text is constructed as it is, and hence why it is effective, or not as effective as it might be, we depend on being able to locate its particular features within the overall multidimensional space that is defined by our functional model of language. (p. 134)

It is critical, when examining texts and evaluating discourse, to consider the context or discipline in which the text or discourse occurs. "This reasoning may involve all the dimensions of the structure and process of language: stratification, instantiation, metafunction, and the biaxial (paradigmatic and syntagmatic) matrix within which any given feature is ordered and from which it derives its value in the system" (Halliday, 2005, p. 134). Each of these features of language combine to make meaning in unique ways determined by the context in which the language is used. Mathematically speaking, these linguistic features equate to symbols, words, lexical bundles, tables, graphical representations, and diagrams. These features work simultaneously to both solve problems and communicate findings. Instruction in the functional linguistics of mathematics, therefore, may aid students in the transfer of procedural knowledge to application-based assessment.

In fact, Schulze (2015) maintains that "systemic functional linguistics has proven to be a significant tool for analyzing and teaching academic language, specifically the rhetorical tools and language patterns typically used to make meaning in various content areas" (p. 110). Largely due to the specialization of disciplinary text at the secondary mathematics level, it is increasingly necessary to instruct students in the functional linguistics of mathematics. Fang & Schleppegrell (2010) explain

> As educational knowledge becomes more specialized and removed from students' everyday experiences, the language that constructs such knowledge also becomes more technical, dense, abstract, and complex, patterning in ways that enable content experts to engage in specialized social and semiotic practices. This means that each secondary subject has specialized ways of using language that may pose comprehension challenges to adolescents. The basic reading skills and generalizable strategies that students learn in elementary school are inadequate in preparing them for these new challenges. (p. 596)

Fang & Schleppegrell (2010) hold that because disciplinary texts generally do not follow typical lexical patterns of non-academic text or colloquial linguistics, students often experience "significant comprehension challenges" (p. 588) when faced with academic texts. Unfortunately, however, in a meta-analysis of various studies in mathematics pedagogy, Leshem & Markovits (2013), found no teachers studied regarded mathematics as a language to be learned. However, "mathematics as well as English as a second language do not develop naturally as a child develops a natural language…classroom activities in mathematics…should engage learners in authentic, real-life functional use of the language" (p. 214). Teachers must aid students in recognizing different language structures that are unique to mathematics and assist students in extracting meaning from these structures (Fang & Schleppegrell, 2010).

Kan and Bulut (2015) emphasize the necessity for students to obtain fluency in both mathematical syntax and vocabulary when solving problems. It is important to note that students face difficulty with mathematical vocabulary due to the duality of many mathematical terms (Hyland & Tse, 2009). Take the mathematics vocabulary word for arithmetic average, "mean," for instance. Outside of mathematics "mean" takes on an entirely different meaning. In algebra, the term "root" in the phrase "root of a function" refers to an input value that results in an output of zero. Meanwhile, in arithmetic, the term "root" in phrases such as "square root" refers to a value, when multiplied by itself a given number of times, equals a radicand. In language classes, however, "root" may refer to the base word of a vocabulary term. And, in science classes, "root" refers to the underground portion of a plant. Because these dual meanings occur frequently in mathematics, a thorough examination of the linguistics of mathematics is necessary in preparing students to transfer mathematical knowledge and to communicate mathematically. "Teachers need knowledge about language and tools to analyze language to understand the demands their subject matter poses to students, to support their students' literacy development and to critically approach the texts they use" (Achugar, Schleppergrell, & Oteíza, 2007, p. 8).

Lexical Bundling

"Some of the words and symbols used to communicate mathematical ideas can sometimes be misinterpreted by learners in their attempt to imitate their teachers" (Mulwa, 2015, p. 27). An analysis of lexical bundles may assist teachers in remedying this confusion. Lexical bundles are groupings of words that frequently recur within a text/transcript that carry specific meanings when strung together.

Content specific bundles. Lexical bundles can be classified as either *content specific lexical bundles* or *stance bundles*. Examples of content specific lexical bundles in mathematics include “simplify the expression,” “find the sum,” “take the square root,” “combine like terms” and “balance the equation.” Hyland & Tse (2009) establish that lexical bundles

> are an important part of a discipline’s discoursal resources but enormously complicate the business of constructing general word lists. By breaking into single words items which may be better left as wholes, vocabulary lists simultaneously misrepresent disciplinary specific meanings and mislead students. (p. 119)

For this reason, it is important to teach content specific lexical bundles in addition to traditional vocabulary lists.

Stance bundles. In addition to content specific lexical bundles, stance bundles are lexical bundles that convey messages regarding attitudes and feelings. Herbel-Eisenmann & Wagner (2010) conducted a content analysis study of mathematics texts and classroom transcripts that illuminates the power of stance bundles within the affective domain of mathematics instruction. These bundles represent almost half of the lexical bundles found in mathematics classroom transcripts and texts and, therefore, cannot be dismissed. Stance bundles found in mathematical texts and classroom transcripts relate teachers and students to the mathematics discourse and often tend to establish an authoritarian relationship between teacher and student. Many of these stance bundles send the message that “[teachers] alone have the authority to make [problem solving] choices in mathematics classrooms” (p. 61).

In teaching the problem-solving process necessary for tackling application-based problems, there is concern that these types of lexical bundles establish a teacher-driven approach to problem solving. Teachers utilizing the FLMI model must move from saying "I'm/We're/You're going to…" to "What should I/we/you do…" in modeling problem solving and assisting with guided practice. By transferring problem solving responsibility from teacher to student, students become active problem solvers as opposed to procedure repeating robots. Herbel-Eisenmann, Wagner, and Cortes (2010) add that "because lexical bundles are mundane and often go unnoticed, we see them as being part of a hegemonic practices in the mathematics classroom, which are structured by certain kinds of positioning and authority relationships" (p. 28). It is critical that teachers examine the use of stance bundles as well as content specific bundles within their instructional dialogue and mathematical texts.

FLMI as a Means for Social Justice

Weist et al. (2007) argue that quantitative literacy instruction fuels social justice by means of better preparing all individuals for financial success, civic responsibility, and personal decision making.

> Developing a quantitatively literate citizenry is not only important for creating a more effectively functioning society but also is a matter of social justice in that it places numeric understanding in the hands of "ordinary" citizens, preparing them to function— for example—as informed voters and consumers. Without quantitative understanding in this Information Age, laypersons may be relatively powerless compared with a small number of individuals with specialized knowledge. (p. 47)

A quantitatively literate person is better equipped to make decisions regarding careers, finances, politics, medical needs, etc. This numerical skill set, all too often, is reserved for those students who are privileged by class or socioeconomic status. Unfortunately, underprivileged students are often less apt to attain mathematical literacy because of factors beyond their control. Students in minority groups and lower socioeconomic groups find mathematical texts difficult to understand and lack the mathematical communication skills necessary in developing quantitative reasoning (de Freitas & Zolkower, 2009). "Without a literacy of mathematics and social justices, students will be at the mercy of sociopolitical and economic systems of oppression" (Bond & Chernoff, 2015, p. 24).

Furthermore, marginalized students often arrive at mathematics with predetermined feelings of inadequacy; thus, it is the teacher's duty to empower students through rigorous instruction that compels students towards intensive engagement with mathematical concepts. Powell and Brantlinger (2008), as cited by Larnell, Bullock & Jett (2016), write

> An objective of critical mathematics ought to be to engage students, socially marginalized in their societies, in cognitively demanding mathematics in ways that help them succeed in learning that which dominant ideology and school practices position them to believe they are incapable. (pp. 424-425)

Larnell, Bullock and Jett (2016) point to *critical mathematical literacy* as a means for social justice. In comparison to typical mathematics instruction, including commercially produced investigative tasks, which is neutral and apolitical, *critical mathematical literacy instruction* reinvents mathematical instruction and "aims to reinvent and show…that mathematics education is political" (p. 21). To reach and engage marginalized students in mathematics instruction, the instructional tasks must be relevant to the lives of marginalized students. It must not be neutral and apolitical.

> Whether inside or outside of school, mathematics is political. Mathematics teaching and learning are certainly political acts – connected to the preservation of privilege, the maintenance of oppression, and the capacity to see both clearly. Despite increased attention to equity, access, and social justice in mathematics education discourse, there is still great need to clearly and deeply conceptualize these terms for the purposes of mathematics teaching, research, and development both professional and curricular." (Larnell et al., 2016, p. 26)

The FLMI model aims to enable students to tackle complex mathematical problems and engage students in authentic investigative tasks that are relevant and political to break down the barriers between the discipline of mathematics and the difficulties that marginalized students face in the study of mathematics. Furthermore, the FLMI model is designed to prepare students for future success in their daily lives by developing and honing quantitative literacy skills.

Conclusion

This chapter has discussed a wealth of literature that frames, supports, and informs the FLMI model. Chapter Three: "Methodology" outlines the action research methods utilized in this study and defines the participants and research setting. Chapter Four: "Findings, Discvoeries, Reflections, and Analyses" provides a description of the study outcomes using descriptive statistics and anecdotal narratives. Finally, Chapter

Five: "Conclusions and Suggestions for Future Research" delineates an action plan for further implementation of the FLMI model as well as the role of the teacher-researcher as a curriculum leader. Additionally, it includes recommendations for future research to be conducted concerning the FLMI model.

CHAPTER 3

METHODOLOGY

Introduction

Educators often look to research to guide their practice; however, the traditional educational research typically found in academic journals is generally conducted by individuals "who are somewhat removed from the environment they are studying" (Mertler, 2014, p. 7). For this reason, educators find little practical use in traditional research findings because the researchers fail to consider the specificity of the local classroom. Action research, on the other hand, is a from-the-ground-up style of research that begins with problems encountered by professionals in their own specific educational environments. The purpose of action research, in contrast to that of traditional educational research, "is to address local-level problems with the anticipation of finding immediate solutions" (p. 12). It is for this reason that action research is the methodological framework for this study.

Purpose of the Study

This study is designed to examine and describe the effect of the FLMI model on student perceptions of and achievement on application-based tasks in a quadratics unit in Algebra 2 at BHS. The action research outlined in this chapter is designed to answer the RQ: To what extent does the FLMI model affect student perceptions of and performance on application-based assessments of quadratics in Algebra 2 courses at the secondary level? The outcomes of this study are used to develop an action plan for improving the teacher-researcher's professional practice and growth.

Statement of the Problem of Practice

BHS students are not adequately prepared to apply algebra skills in authentic application-based scenarios.

Research Design

The following paragraphs detail the specific research design for this action research project. Background information regarding the research site, the teacher-researcher, and student-participants is provided. Additionally, procedures used for data collection and analysis are outlined.

Research Site

BHS served as the research site for this study. Serving approximately 1000 students, BHS is particularly diverse with 32.6% of its student body White, 30.9% African American, 31.5% Hispanic, and 5% other. Additionally, 79% of the BHS student body receives free and reduced meals (Noel, 2015). Course offerings include remedial courses in mathematics and English, college prep courses in all core subjects as well as foreign language, physical education, Air Force JROTC, nursing, machine and manufacturing, agricultural studies, business, and journalism, and advanced-placement courses in English, mathematics, history, and science. BHS houses a freshman academy as well as a newcomer academy for English language learners new to the United States. Additionally, BHS has recently established a Careers Academy offering vocational courses and certifications to incoming freshman. At the time of data collection, the inaugural class of the BHS career academy program were eleventh graders and taking Algebra 2. The teacher-researcher has considered the effect of this shift in curriculum when examining the results of the study.

Teacher-Researcher

The teacher-researcher is a senior member of the mathematics department at BHS and has completed thirteen years of teaching Algebra 2 among other subjects. She possesses a master's degree in education and is currently a doctoral candidate at the University of South Carolina. The teacher-researcher was responsible for all instruction during this study. Additionally, the teacher-researcher is responsible for accurately reporting the findings of this study and reflectively developing an action plan for progressing forward in her instruction and professional development.

Student-Participants

The Algebra 2 college prep students included in the study were chosen using convenience sampling as the teacher-researcher engaged in research with those students already enrolled in her courses at the time of the study. The sample was comprised of one section of Algebra 2 at BHS during the spring semester of the 2017 – 2018 academic year. Twenty-three students were included in the sample, of those 13 were male and 10 were female. Ten students were seniors, twelve students were juniors, and one student was a sophomore. Seven students had Individualized Education Plans (IEP), one had a 504 accommodation plan, and ten were English Language Learners (ELLs). Eleven students were Hispanic, six were white, and six were black.

Data Collection

For this study, the teacher-researcher utilized a mixed methods design including both a one-group pretest-posttest design and a qualitative survey with personal narratives to describe the effect of the FLMI model. Mertler (2014) defines this type of research as *pre-experimental* indicating that, as in experiments, a treatment is applied and results are recorded to determine the effect the treatment creates.

Quantitatively, the study utilized a one-group pretest-posttest design in which a pretest is administered to establish a baseline. After the treatment was applied, a posttest was administered for comparison to the baseline. This comparison allows for any changes to be documented that occurred over the course of time that the treatment was applied. In the case of this study, the treatment applied was the FLMI model and the pretest and posttest were teacher-researcher created.

Prior to any instruction, a pretest was administered to assess students' ability to apply mathematical concepts to application-based tasks. During the study, students received daily instruction following the FLMI model over the course of the entire quadratics unit. At the culmination of the unit, students were assessed again on their ability to complete application-based tasks. The pre- and post- test were direct parallels of each other but contained a variety of functions and values to prevent student responses based on recall and familiarity. Coding was used when recording pre-test and post-test scores to ensure anonymity of student-participants.

Further, qualitative data collected via surveys was collected prior to and after instruction using the FLMI model. These surveys assessed student perceptions of application based assessments in mathematics class. As with the pre- and post- test data, survey data was coded to retain anonymity.

Statistical Analysis

Because the sample collected for this study lacks randomization, because the sample contained a smaller number of participants than required for inferential calculations, and because the one-group pretest-posttest design does not call for group comparisons, it is inappropriate to use inferential statistics such as chi-squared tests (Mertler, 2014). Instead, descriptive statistics and graphical displays have been used to analyze the data that was collected in this study. Descriptive statistics are "simple mathematical procedures that serve to simplify, summarize, and organize relatively large amounts of numerical data" (p. 169). These types of calculations involve measurements of center, dispersion, position, and relation. While measures of center and dispersion are appropriate in a pretest-posttest design, it is less appropriate to utilize measures of position or relation such as percentiles and correlation. Survey data has been analyzed using numerical summaries representing student perceptions of application-based assessments. Descriptive statistics are preferable for use in action research as the purpose of action research is "gaining insight, developing reflective practice, effecting positive changes in the school environment…and improving student outcomes" (Mills, 2007, p. 5). It is through the use of descriptive statistics that such objectives can be met.

While pre-test and post-test scores are analyzed and presented in the report of the findings of this study, an analysis of student gain is the focus of the discussion of findings. Gain is defined as the difference between posttest and pretest scores where a positive value indicates an increase in score from pre-test to post-test and a negative value indicates a decrease in score. Data collected appears roughly symmetric; therefore, the mean and standard deviation are reported.

Ethical Considerations

As with all research, it is the responsibility of the teacher-researcher to ensure that the study does no harm to its participants (physically, mentally, or emotionally) and that all parties are informed, remain anonymous, and are provided access to the results of the study.

Full and Informed Consent

All participants (and participants' guardians) in the present action research study received full and informed consent letters and consent forms informing participants of the research to be conducted, their role in the research, and their rights as participants. Included in the full and informed consent letter was a summary of the project, data collection procedures, expected benefits of participation, possible risks, guarantee of confidentiality, contact information, and information pertaining to the publication and release of data. Participants who did not provide consent via signing the informed consent form are not included in the publication of this study.

Participant Confidentiality

Participants in this study shall remain anonymous. All data has been coded to ensure the confidentiality of participants.

Instructional Responsibility

The primary concern of the teacher-researcher is that all students are provided quality instruction. At no time, should any student be denied rigorous and complete instruction. Because the FLMI model does not change the core instruction component and only bookends this instruction with vocabulary and socio-mathematical assessment while embedding the content in a thematic investigation, student-participants in this study received appropriate and quality mathematics instruction.

District Research Procedures

In compliance with the school district's "Accountability and Quality Assurance – Research Guidelines" (Greenville County School District, 2016), school level administration was directly involved in the planning and conducting of this study. The teacher-researcher obtained written permission from school level administration prior to collecting and publishing data. Finally, the teacher-researcher is obligated to provide a copy of the DiP and presentations/trainings upon request to all district and school level administration; this provision is to be free of charge in exchange for school district cooperation.

Conclusion

This chapter has detailed a mixed methods action research study to determine the effect of the FLMI model on student perceptions of and achievement on application-based tasks in a quadratics unit in Algebra 2 at BHS. This study occurred over the course of one instructional unit during the 2017-2018 academic year. The teacher-researcher was solely responsible for instruction during the study and adhered to the aforementioned ethical guidelines to protect and properly instruct the students under her care. This DiP discusses and reports the findings using descriptive statistics and personal anecdotal narratives in Chapter Four: "Findings, Discoveries, Reflections, and Analyses". These findings inform an action plan for further instruction, professional growth, and research that is outlined in Chapter Five: "Conclusions and Suggestions for Future Research."

CHAPTER 4

FINDINGS, DISCOVERIES, REFLECTIONS, AND ANALYSES

Introduction

This DiP set out to evaluate the teacher-researcher created instructional model, the FLMI model, by addressing the following RQ: To what extent does the FLMI model affect student perceptions of and performance on application-based assessments of quadratics in Algebra 2 courses at the secondary level? At the onset of this research study, the teacher-researcher was inclined to address the following PoP: BHS students are not adequately prepared to apply algebra skills in authentic application-based scenarios.

The teacher-researcher utilized a mixed-methods action research procedure including both a one-group pretest-posttest design and a qualitative survey to collect data regarding the effectiveness of the FLMI model. Prior to instruction, the student-participants were assessed on their ability to apply algebraic skills in solving quadratic functions to quadratic modeling word problems. Additionally, a qualitative survey was utilized to assess student perceptions of word problems in Algebra. Both pretest and pre-survey results serve as baseline data for the present study. Post instruction, student-participants were again assessed via post-test and post-survey. Finally, anecdotal evidence is provided to offer insight regarding the effect of the FLMI model on student performance and perceptions and highlight lesson activities utilized in the FLMI model.

Findings

Table 4.1 provides the descriptive statistical analyses of the pre- and post-tests as well as gain in scores. Each distribution is roughly symmetric and, therefore, little effect is made on the data in regards to skewness. As such, particular attention should be paid to the mean and standard deviation as they are appropriate measures for analysis of non-skewed data. However, a five number summary (Minimum, Quartile 1, Median, Quartile 2, and Maximum) is also provided for each data set to supply additional comparison value. Note a nearly 50% increase, on average, in student achievement from pre- to post-test. Because randomization and sample size are insufficient, tests for significance are not provided. However, a substantial gain can be seen from pre- to post-test in both measures of central tendency (mean and median) as well as within the five number summary for each test. Most dramatically, increases of 56% and 47% on quartile 3 scores and median scores respectively indicate a substantial rise in achievement among the upper 50% of test scores. At the lower end, a 20% and 40% gain on minimum and quartile 1 scores respectively indicate a smaller, yet still substantial, increase among the lower 25% of test scores. Finally, both pre- and post-test scores carry standard deviations of roughly 11% each indicating that scores for each test were similarly distributed.

Table 4.1 - Pre-Test/Post-Test and Gain Statistical Analyses

	Pre-Test	Post-Test	Gain (post-test minus pre-test)
Mean	25.913	75.174	49.261
Standard Deviation	11.024	10.824	14.623
Minimum	14	55	20
Quartile 1	23	71	40

Median	27	76	47
Quartile 3	32	83	56
Maximum	36	93	41
Outliers	0, 9	47	none

Pre- and post-survey results can be seen in Table 4.2. Each survey stem (as seen in table 4.2) was accompanied with a Likert scale ranging from "strongly disagree" to "strongly agree." "Strongly disagree" was assigned a value of 1 and "strongly agree" was assigned a value of 5. Students were asked to rank each statement from 1 to 5 accordingly. Table 4.2 shows the average rank score for each stem on both the pre-survey and post-survey. Additionally, gain (post-survey average – pre-survey average) is shown to assist in analyzing the effect of the FLMI model on student perceptions of application-based instruction and assessment. A positive gain indicates that students came to agree more with the statement after instruction via the FLMI model. Likewise, a negative gain indicates that students came to disagree more with the statement after instruction via the FLMI model. Most significant changes in student perceptions can be seen in "I enjoy doing word problems in Algebra" (+1.41) and "Word problems are more difficult than math problems that are not word problems" (-1.12). Least significant changes in perceptions can be seen in "I prefer to do problems that involve real world scenarios than problems that do not" (+0.17) and "I generally know how to set up the calculations for a word problem without help" (+0.23). Nevertheless, each of these stems did show an increase in average rank.

Table 4.2 – Pre-Survey and Post-Survey Results

Survey Stem	Pre-Survey Average Rank Score	Post-Survey Average Rank Score	Gain
I feel confident when I see a word problem on a quiz or test.	3.00	3.88	0.88
I know how to read a word problem and identify the important information.	3.53	3.82	0.29
If someone helps me to set up the calculations for a word problem, I can solve it.	3.71	4.06	0.35
I generally know how to set up the calculations for a word problem without help.	3.18	3.41	0.23
I enjoy doing word problems in Algebra.	2.24	3.65	1.41
Word problems are more difficult than math problems that are not word problems.	3.24	2.12	-1.12
I prefer to do problems that involve real world scenarios than problems that do not.	3.24	3.41	0.17
I prefer projects that involve real world problems instead of quizzes or tests that do not.	3.06	3.65	0.59
I prefer a teacher who explains how math relates to the real world than one who focuses only on how to do calculations.	3.76	4.12	0.36

Additionally, two open-ended survey questions were included. Table 4.3 lists select student responses to each of these questions both pre- and post- FLMI. While pre-survey responses mostly carried a negative view of word problems and real-world scenarios, not all students responded negatively. Post-survey responses were categorically more positive in perception of word problem and showed confidence among student-participants regarding their ability to tackle application-based assessments.

Table 4.3 – Select Open-Ended Survey Question Responses

	Describe your feelings about word problems and real world scenarios in math.	When you come to a word problem on a test or a quiz what do you generally do?
Pre-Survey Responses	"I hate word problems." "I believe that word problems make things much harder." "I prefer real world scenarios."	"Skip it." "I look at it and think, 'nope! Not in the mood for that.' Word problems add too much un-needed information to it that everything becomes confusing." "Try to solve it."
Post-Survey Responses	"I still don't love them, but I'm getting better at them." "They make math more interesting." "I don't want to do them if I don't have to, but I can."	"Look at what the problem is asking me to find first. Then set up an equation or graph to help me solve it." "Highlight and circle the critical information. Then, I decide on a plan for solving it." "I re-read it and look for key phrases to help me get started."

Anecdotal Evidence

Prior to FLMI model instruction. Prior to the implementation of the FLMI model, student-participants frequently avoided completion of application-based tasks. In particular, students avoided completing word problems on tests and quizzes as well as failed to turn in assignments that mostly involved word problems. This can be seen, as well, in pre-survey responses to open-ended survey question #2 where students indicate that they generally skip word problems on tests or quizzes. One student even wrote, "I look at it and think 'Nope! Not in the mood for that!"

Students who did not skip or avoid these assignments and problems, often met with failure. In many cases a simple guess was made on each word problem and students moved on hoping to earn enough points on the skill and drill portion of class assignments to receive credit for the course. A small portion of student-participants would make a valiant effort, yet still come up short in their responses.

The student-participants were certainly frustrated by class assignments involving algebraic application. Furthermore, the teacher-researcher was frustrated by her failure to motivate students to attempt them. During the pre-test, for instance, students simply grumbled and the teacher-researcher found herself directing them to "do their best" while desperately hoping they would not simply leave the entire assessment blank.

During FLMI model instruction. Initial phases of the implementation of the FLMI model presented similar challenges. An anticipation guide (Appendix H) was provided alongside the thematic investigation (Appendix G). Students were asked to read the thematic investigation and answer the questions on the anticipation guide without attempting to solve the problems in the thematic investigation themselves. Many students expressed fear of the thematic investigation and wrote responses on the anticipation guide that indicated they simply "did not know" how to do word problems. The initial encounter with the thematic investigation seemed to invoke frustration for student-participants. For example, one student wrote "I don't know" in response to every question on the anticipation guide. When the teacher addressed this with the student and asked the student to re-attempt the assignment, he became agitated and threw the paper away.

Upon the initial reading of the thematic investigation and completion of the anticipation guide, student-participants were provided daily instruction according to the FLMI model in solving quadratic equations. Each lesson began with class discussions of the linguistics that would be used in that day's lesson along with a graphic organizer, vocabulary list, or similar disciplinary-literacy instructional tool. For example, a lesson in the first week of the project began with a class discussion concerning the concepts of roots, zeroes, and solutions as they applied to all types of equations and problem-based scenarios. This class discussion was followed with examples of word problems which required finding a "root" or "zero" (both synonymously meaning "solution to an equation that is set to zero) to an equation without directly asking for such.

These examples were of lesser difficulty than the quadratic applications that would follow during the skill portion of the lesson in order to ensure student understanding of the linguistics involved without creating mathematical confusion. For instance, one example read:

> Students in Mrs. Robertson's course are each given $10 of play money. Each day they have the opportunity to spend $1 to buy a headphone pass in order to use headphones to listen to music during the classwork portion of class. How many times can a student purchase a headphone pass over the course of the semester

before they have no more play money assuming they can obtain no more play money than they were initially given?

These examples, while providing simple to derive solutions often, created complex linguistics situations in which students could create graphs, tables, diagrams and equations to find the roots, zeros, and solutions. In this particular example, the linguistic lesson to be learned was that graphs, tables, diagrams, and equations are all tools used to describe a mathematical problem that determines when a specific value reaches zero, i.e. to find the root or zero.

Student-participants found these kinds of linguistics lessons unrelated and irrelevant to their learning of quadratic application but over the course of the unit began to appreciate it and saw its relevance. This was evidenced during debriefing with students when they indicated that they eventually understood its purpose. One student claimed, "I didn't see the point at first. It all seemed like common sense, but when you put it together with the harder lessons we learned I saw how it all tied together." Another student said, "I thought doing all that math for the easy questions was stupid, but it made the harder problems easier."

Following the linguistics portion of the daily lesson, instruction was given on a specific method or approach for solving quadratic equations. These lessons incorporated multiple representations (equations, graphs, tables, diagrams, etc.) whenever possible and specifically aligned to a portion of the thematic investigation. It is also of value to note that during these lessons the teacher incorporated stance-bundling that imparted mathematical authority and flexibility in solving problem to the student.

On the same day that the aforementioned linguistics lesson occurred, students were given direct instruction in the use of the quadratic formula to solve quadratic equations whose roots could not be found using factoring or the square root method for solving quadratic equations. This lesson was structured similarly to other lessons that occurred over the course of the semester and was mostly teacher centered. Students listened as the teacher lectured, took notes, and answered questions as they were posed for whole-class response and discussion. Examples were provided as the teacher modeled the use of the quadratic formula. These examples were not application-based and were followed with practice problems for the students to complete and have checked prior to moving to the remaining portion of the daily lesson. Student-participants found this portion of the daily lessons familiar and comfortable. During debriefing, they indicated that this was "normal" teaching so it was a comfortable approach for them.

At the end of each daily lesson, students completed socio-mathematical assessments of the daily lesson. Students were grouped to complete tasks that included both skill and drill and application-based problems. For each application-based problem students were required to work together. On most occasions, they chose to work together on the skill and drill problems as well. As they worked, the teacher-researcher moved from group to group asking pointed questions and assessing student feedback. During these tasks, students were required to either write an explanation of their work, or present their solution and problem-solving process to their peers.

For example, the day of the lesson mentioned above, students were given the following task:

In your groups, combine the skills that you have learned today (using multiple representations to find zeros and roots AND using the quadratic formula to solve a quadratic equation) to help you solve this problem: Andy is shooting a bottle rocket. He knows that the rocket should follow a path that can be modeled by the equation $h(t) = -16t^2 + 58t + 3$, where $h(t)$ represents the height of the rocket in t seconds. When will Andy's rocket return to the ground? When you have agreed upon a method for solving this problem and have utilized more than one multiple representation to justify your solution, prepare a statement to be shared with the class explaining how you found your solution and why you chose to utilize the representations that you chose.

The purpose of this activity was to have students connect the linguistics portion of the lesson with the skill portion of the lesson in such a way that they could arrive at a complex solution to an application-based quadratic problem. In this instance, they were required to utilize three skills learned during the lesson. First they must conceptually reframe the problem as a request to find the root or zero of the function. Then, they must associate this problem with the quadratic formula and accurately apply the formula to arrive at a numeric solution. Finally, they were expected to utilize multiple representations to justify their solution and present it to the class.

Initially, students were hesitant to complete the application-based portion of these assignments and even more hesitant to complete their explanation or presentation of the solution and problem-solving process. As students saw that the teacher-researcher was persistent in these requirements, they gave in slowly, showed cooperation, and made progress in their understanding of the mathematical concepts.

Post FLMI model instruction. At the culmination of the unit, students revisited the thematic investigation. They were not allowed to ask the teacher-researcher for help on the application portion of the assessment, but were allowed to seek help regarding the skills associated with completing the application-based tasks. Students continued to express frustration with the assignment, but their performance on the task indicated a conceptual understanding of both the mathematical skills as well as the linguistics involved in the problem-solving.

As students turned in the assignment, they expressed fear that they had performed poorly. However, when their papers were reviewed, the students had performed well and were met were met with success. One student said, "I think I failed this" as she handed her work in; however, her paper (Figure 4.1) indicates that she had mastered the concepts. This is also evidenced in post-survey data. During debriefing, one student said, "I didn't realize how much better I had gotten at word problems."

Discussion of Findings and Results

Both the results of the pre- and post- tests as well as those of the pre- and post-surveys indicate that the FLMI model has the potential to improve both student performance on and perception of application-based assessments in Algebra 2. Furthermore, the anecdotal evidence described above indicates that the FLMI model improved student confidence in approaching word problems and that the teacher-researcher's persistence in the model impacted student performance.

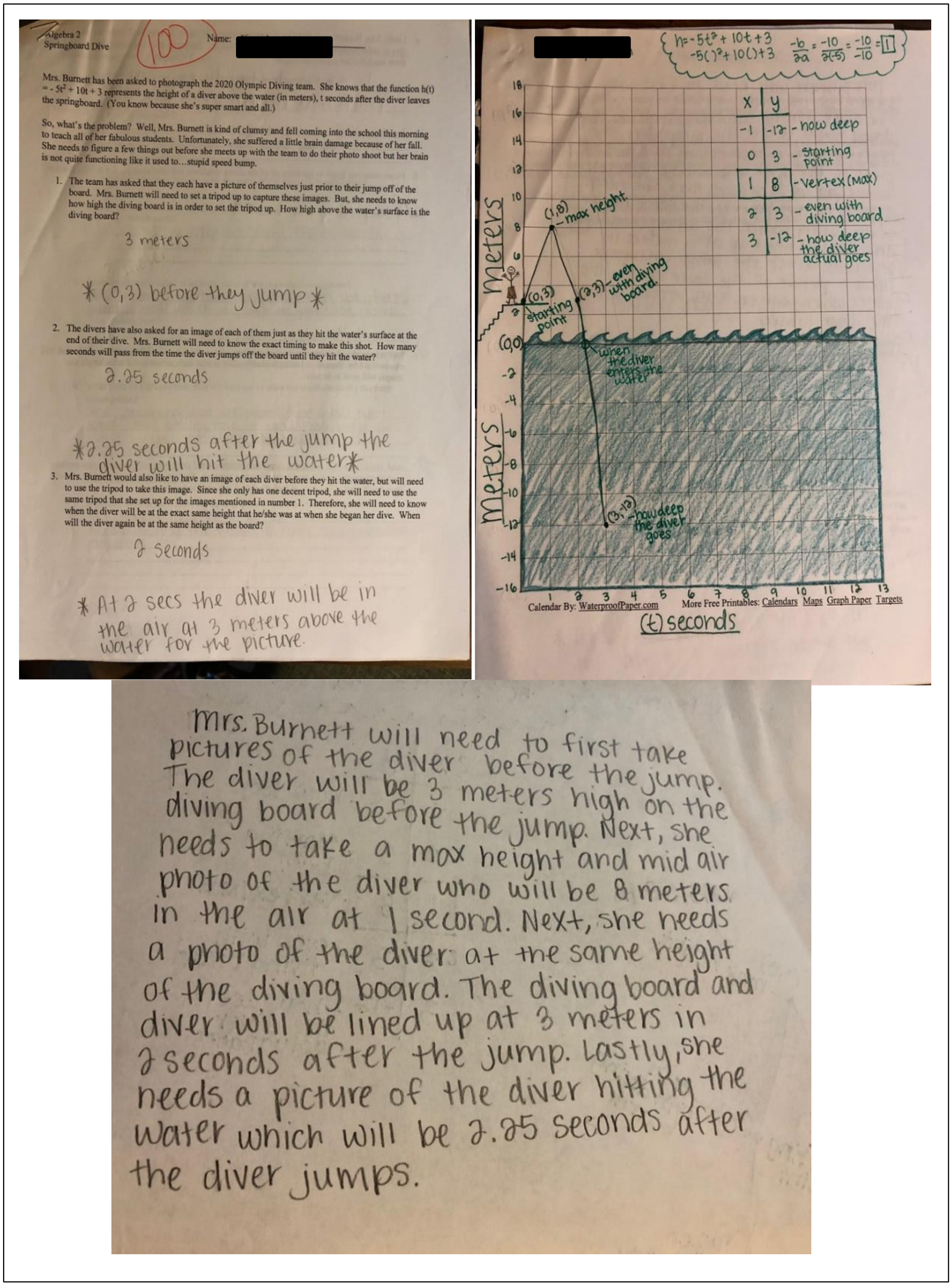

Figure 4.1: Example of Student Work on Thematic Investigation

The FLMI model resulted in significant gain in scores on a quadratic modeling assessment in Algebra 2. Most interestingly, the FLMI model appears to have affected student perceptions both regarding assessment and instruction as well as personal confidence and preference regarding word-problems and real-life mathematics in the Algebra 2 classroom. Students gained appreciation for word problems and confidence in successfully completing application-based assessments. The RQ (To what extent does the FLMI model affect student perceptions of and performance on application-based assessments of quadratics in Algebra 2 courses at the secondary level?) is best answered upon analysis of the findings presented in Tables 4.1, 4.2, and 4.3. This analysis portrays a preliminary finding of success of the FLMI model.

Implication of Findings

The FLMI model, a teacher-researcher created instructional model, appears to have potential for improving overall success on application-based assessments in mathematics classrooms at BHS. However, these findings are solely based on data collected during one unit in one course at BHS. Further, these findings are based on data collected in only the teacher-researcher's own classroom.

Nevertheless, the positive outcomes of this study indicate that the FLMI model should be expanded and its effectiveness should continue to be monitored. It is necessary to consider the transferability of these findings to other units, courses, and instructors at BHS. As such, more research is necessary in determining the sustainability and success of the FLMI model across other units, courses, and instructors. Recommendations for further research are made in the subsequent chapter of this DiP.

Conclusion

The present action research study to determine the effect of the FLMI model on student perceptions of and achievement on application-based tasks in a quadratics unit in Algebra 2 at BHS has shown a positive outcome and indicates a potential for the FLMI model to serve as an instructional tool for mathematics instruction at BHS. Both post-test scores and post-survey responses indicate substantial positive gains in achievement and perception on application based assessments. This chapter has reported these findings using descriptive statistics and discussed these findings in light of the research-setting as well as indicated a need for further research. An action plan for further instruction, professional growth, and research is outlined in Chapter Five: "Conclusions and Suggestions for Future Research."

CHAPTER 5

CONCLUSIONS AND SUGGESTIONS FOR FUTURE RESEARCH

Introduction

Recap of PoP, RQ, and Purpose

This study addressed the following PoP: BHS students are not adequately prepared to apply algebra skills in authentic application-based scenarios. The teacher-researcher set out to remedy the PoP using the FLMI model and utilized action research to examine this model's effectiveness. This paper has described the effect of the FLMI model on student perceptions of and achievement on application-based tasks in a quadratics unit in Algebra 2 at BHS and directly addresses the RQ: To what extent does the FLMI model affect student perceptions of and performance on application-based assessments of quadratics in Algebra 2 courses at the secondary level?

Recap of Methodology

The teacher-researcher implemented a mixed methods research design to determine the effectiveness of the FLMI model on both student perceptions of and performance on application-based tasks. This design incorporated both quantitative and qualitative methods via the use of both pre- and post-tests as well as survey and personal anecdotal data. Data collection occurred over the course of one instructional unit at BHS during the 2017-2018 academic year and involved a convenience sample of 23 college prep students in tenth to twelfth grades.

Recap of Findings

The data from this study has indicated a positive gain in both student achievement on application-based assessments and in student perceptions regarding application of algebraic skills to real-world problems. This is demonstrated in a nearly 50% gain from pre- to post-test scores and in survey results showing that the student perceptions of application-based tasks improved after implementation of the FLMI model. Additionally, the teacher-researcher's experiences during instruction and interactions with students detailed in Chapter 4 indicate a successful implementation of the FLMI model with positive outcomes. Therefore, the FLMI model may serve to improve student perception of and performance on application-based tasks in algebra. As such, the findings of this study have been used to develop an action plan for improving the teacher-researcher's professional practice and growth.

This chapter outlines the importance of reflection in developing an action plan, the role of the teacher-researcher as a curriculum leader, an action plan for broader implementation of the FLMI model in mathematics classes at BHS, and implications for future research regarding the FLMI model.

The Importance of Reflection in Developing an Action Plan

Action research creates opportunities for teachers to improve their instructional practices; "choosing not to engage in the process can almost be viewed as unethical" (Dana & Yendol-Hoppey, 2014, p. 149). Furthermore, action research is "an extremely appropriate time for professional reflection" (Mertler, 2014, p. 214). Furtado & Anderson (2012) suggest that reflective practices promote creative teacher leaders who engage in professional discourse, achieve gains in student performance, and sustain confidence and growth in practice. Professional reflection in action research "ensures a pathway for an emergent and organic teacher leadership for teachers equipped with the necessary professional exploration of practice" (p. 561).

As such, the teacher-researcher's stance throughout this action research study has remained reflective at its core. Prior to determining the PoP for the current action research study, the teacher-researcher began a process of reflection and collaboration that led her to the aforementioned PoP and RQ. After an initial reflection of her teaching practice, she realized that she typically struggles with moving students from skill and drill style mathematics to mathematical modeling and reasoning - particularly in regards to application problems in Algebra 2. This reflection process prompted dialogue within the Professional Learning Community (PLC) that reflected a systemic weakness in the application area of algebra within all Algebra 2 classes at BHS. Upon this realization, it became apparent that it was necessary to look at school data regarding mathematics performance on application-based assessments. Analysis of schoolwide test data confirmed a weakness in application of Algebra skills.

While this reflection process has involved significant introspection, the teacher-researcher has also engaged in reflection through collaboration with colleagues, school administration, and student-participants. Much of this collaborative reflection has occurred within the PLC and through debriefing sessions with school administration. Class discussions aided in reflective collaboration with student-participants. Furthermore, collaboration with peers and instructors in the University of South Carolina's College of Education has proven helpful as research was conducted, data was analyzed, and the action plan was developed.

Because conducting action research naturally occurs within the teaching practice of effective teachers, effective teachers are reflective teachers and are, therefore, perpetually engaged in some form of action research. Action research is meant "to improve one's own professional judgement and to give insight into better, more effective means of achieving desirable educational outcomes" (Mertler, 2014, p. 13). Therefore, a teacher's failure to capitalize on problems experienced in his or her classroom by conducting some form of action research results in a missed opportunity to advance his or her teaching practice. This missed opportunity is, in effect, the failure of a teacher to fulfill the responsibilities of the profession. As Dewey (1938) proclaimed, "the teacher's business is to see that the occasion is taken advantage of" (p. 71). For these reasons, the teacher-researcher is obliged to continue in her efforts to remedy the applied mathematics shortcomings at BHS and to continue researching the effectiveness of the FLMI model.

In action research, as with the teaching practice, continuous reflection and research must never cease. Both the system, as a whole, and the individual student and teacher benefit when educators work toward finding solutions to specific problems in the local classroom. Action research is "an extremely appropriate time for professional reflection" (Mertler, 2014, p. 214). There rests no purpose in conducting action research if reflection of such research is absent. Furtado & Anderson (2012) suggest that reflective practices prepare teacher-leaders who engage in professional discourse, achieve gains in student performance, and sustain confidence and growth in practice. Professional reflection in action research "ensures a pathway for an emergent and organic teacher leadership for teachers equipped with the necessary professional exploration of practice" (p. 561). Thus, the teacher-researcher must continue in her reflective stance and encourage others to reflect on the FLMI model as they begin its implementation in their own classrooms as part of the teacher-researcher's action plan.

Mertler (2014) explains that the teacher-researcher should both reflect on the implications of the study outcomes as they pertain to future professional development (action-*on*-research) as well as reflect on the action research study logistics in regards to conducting future studies (action-*in*-research). Furthermore, such reflective practices involve examining the entire process from start to finish and how the findings may affect future change.

Action-*in*-research addresses the *who, what, and why* questions; Action-*on*-research pursues the *where and how.*

> Reflection is about learning from the critical examination of your own practice but also about taking the time to critically reexamine exactly *who* was involved in the process, *what* led you to want to examine this aspect of your practice, *why* you chose to do what you did, *where* is the appropriate place (time, sequence, location, etc.) to implement future changes and *how* this has impacted your practice. (Mertler, 2014, p. 258)

Both reflection of action-on-research and action-in-research have guided the development of an action plan to effect change in Algebra 2 instruction concerning mathematics literacy and the FLMI model at BHS.

The Teacher-Researcher as Curriculum-Leader

As the action plan is implemented, the teacher-research must assume a position of leadership. Thus she must consider the significance of her role as a curriculum-leader. As a classroom teacher at BHS, the teacher-researcher's role is defined collegially and, thus must be must be grounded in servitude towards students, colleagues, and the community. Sergiovanni (2013), in "Leadership as Stewardship: 'Who's serving who?'," writes

> Stewardship involves placing oneself in service to ideas and ideals and to others who are committed to their fulfillment…it embraces all the members of the school as community and all those who are served by the community. Parents, teachers, and administrators share stewardship responsibility for students. (p. 388)

While the teacher-researcher does not serve an administrative role, she does serve as an ex-officio member of the School Improvement Council (SIC) and as a member of two PLCs within the mathematics department. Her roles in both of these positions empower her to utilize servant leadership to achieve the "shared goals and purposes" (Sergiovanni, 2013, p. 383) of the PLCs and the SIC as well as the faculty at large. As she acts within these leadership positions, she must possess servitude towards the greater school community.

When engaging in and initiating dialogue to enact curricular change, it is imperative that she fosters Open-to-Learning Conversations (OLC) among her colleagues in PLCs and the SIC. Robinson (2013) outlines three values that underpin OLCs and prevent Closed-to-Learning Conversations (CLC). First, is the "pursuit of valid information…[including] thoughts, opinions, inferences, and feelings – anything that affects the views of the participants in the conversation" (Robinson, 2013, p. 311). It is imperative that the teacher-researcher gathers feedback from colleagues as she attempts to lead them towards improvements in praxis. Robinson (2013) suggests "disclosing one's views and the reasoning behind them, seeking feedback from others, and treating one's views as hypotheses rather than as taken-for-granted truths" (p. 311).

The second value underpinning the fostering of OLCs is respect. "Respect for others involves listening deeply, especially when others disagree, and treating others as capable of learning and contributing to one's own learning" (Robinson, 2013, p. 311). Treating colleagues as individuals capable of making valuable contributions is a particularly important component of OLCs. When this value is absent, CLCs are inevitable.

The final value underpinning the process of nurturing OLCs "involves increasing the internal rather than external commitment of teachers to decisions" (Robinson, 2013, p. 311) by remaining honest and transparent. Teacher commitment to shared goals and purposes is increased when leadership is open about the process.

It is critical that curriculum leaders aim to gather valid information, show respect for all stake holders' opinions and capabilities, and remain open and honest about their agendas. As the teacher-researcher works to foster an OLC about the FLMI model with her PLC and as she presents the FLMI model to the SIC, she must possess these values and engage in servant-leadership to promote the overall success of the school community. The teacher-researcher's aim is that her leadership position continually resembles Deal and Patterson's (2013) metaphorical view of "school leaders as potters" (p. 280). That is, "School leaders shape the elements of school culture (its values, ceremonies, and symbols), much the way a potter shapes clay – patiently, with skill, and with an emerging idea of what the pot will eventually look like" (p. 280). It is this patience and skill that will shape the outcome of the action plan as it is implemented over what may be several years.

Action Plan

The intent of the action plan is three-fold. First, the aim of this action plan is to implement curriculum reform that directly improves the performance of students in the teacher-researcher's classroom as they tackle application-based problems. Second, the action plan is designed to address disparity among minority students in regards to successful transfer of mathematics knowledge. And, third, the action plan serves as a catalyst for curriculum change throughout the mathematics department, as well as others, at BHS as teachers will be encouraged to utilize the FLMI model and increase their attention to disciplinary literacy.

The determined action plan involves four tiers or stages in which implementation is to occur: classroom level, PLC level, department level, and school level. The following outlines the implementation of the action plan at each level:

1. Stage One – Classroom Level Implementation: As the current DiP examines the effectiveness of the FLMI model in only one unit of Algebra 2 in one section of the instructor's courses, it is necessary to continue evaluation of the FLMI model over the course of a longer instructional period. For this examination to occur, the teacher-researcher intends to implement the FLMI model as an instructional model for the duration of one semester's course of Algebra 2. Assuming success with this implementation, the teacher-researcher will begin implementation in other courses under her direct instruction such as Algebra 1 or Probability and Statistics.

2. Stage Two – PLC Level Implementation: Upon successful completion of classroom level implementation, the teacher-researcher intends to present the FLMI model and the outcomes of her classroom level implementation to the members of her PLC. In PLC meetings, the teacher-researcher will train her colleagues in the use of the FLMI model and recommend their use of the model beginning with singular units of instruction.
3. Stage Three – Department Level Implementation: Upon successful completion of PLC level implementation, the teacher-researcher intends to work with PLC members to incorporate the FLMI model among additional PLCs. That is, members of the Algebra 2 PLC are also members of other PLCs that the teacher-researcher is not. For instance, one member of the Algebra 2 PLC is also a member of the Geometry PLC while the teacher-researcher is not. This member of the PLC can disseminate the FLMI to the Geometry PLC. In addition to this sort of PLC dissemination, the teacher-researcher may present the FLMI at departmental meetings during the school year and department professional development sessions during summer break.
4. Stage Four – School Level Implementation: Upon successful completion of department level implementation, the teacher-researcher will present the FLMI model to the SIC and seek opportunities through school administration to present the FLMI model to other departments. As the FLMI model is mathematics oriented, this stage of implementation will call for collaboration with members of other departments to adjust the model to suit their content. At this point, the FLMI model may branch out to other areas and become a

family of functional linguistics instructional models such as the Functional Linguistics of Science Instruction Model or the Functional Linguistics of Art Instruction Model.

Of course, assuming success at each of the four stages of the action plan, the teacher-researcher will consider additional stages at the district, state, and national level through the presentation of the FLMI model at professional conferences, workshops, and symposiums.

Curriculum Leader Role in the Action Plan

The teacher-researcher will act as curriculum leader during the implementation of the action plan stages. The following outlines her role in each of these stages.

1. Stage One – Classroom Implementation: Murphy (2013) writes, "successful leaders have the capacity to recognize their own shortcomings, and they take steps to compensate for them" (p. 33). As a curriculum leader, the teacher-researcher must acknowledge her personal instructional practices that are in need of reform and take action to improve or replace them. The intent of the action plan to be implemented at the classroom level is to compensate for weaknesses currently existing in her teaching practice.
2. Stage Two – PLC Level Implementation: Fink & Markholt (2013) call for PLCs that engage directly in improving teaching practice through continued learning. Further, Fink & Markholt (2013) emphasize the need for expert input within the PLC. The teacher-researcher's role in the PLC will be as FLMI expert and lead teacher. While BHS's Algebra 2 PLC was involved in the implementation of the FLMI model from its inception, discussions about

the FLMI will also be initiated and facilitated in the teacher-researcher's secondary PLCs – Probability and Statistics and Algebra 1. The process of implementing the action plan across both of these PLCs is likely to extend for several years following the project and will require dedication and perseverance on the part of the teacher-researcher.

3. Stage Three – Department Level Implementation: Though the teacher-researcher does not serve as the mathematics department chair, she is one of two senior members of the department and will take a curriculum leader role in guiding the department towards curriculum reform in all mathematics content. Brubaker (2004) recommends the introduction of a "model or map that will give participants a sense of direction…[and] at the same time, the leader should make it known that the model or map presented is a starting place or springboard that invites improvement" (p. 132). The FLMI model will serve as this map and the teacher researcher will serve as a resource for teachers of other mathematics courses and in other PLCs for implementing functional linguistics and mathematics literacy strategies in those courses.
4. Stage Four – School Level Implementation: Because the FLMI model is specific to mathematics, implementation at the school level will vary from department to department. However, the essence of functional linguistics and content area literacy must remain at the forefront of curriculum reform discussions and improvement strategies. As Wagner & Kegan (2013) argue, "if we have many improvement priorities, we actually have none. We must choose a priority and stay relentlessly focused on it" (p. 228). Content area

literacy, then, must be a top priority for all stakeholders. The teacher-researcher will use her position as a member of SIC to keep content area literacy and curriculum reform at the top of the school improvement priority list.

Implications for Future Research

While the present DiP has shown that the FLMI model has positively affected both the perceptions of Algebra 2 students at BHS on application-based tasks and their performance on said tasks, the results of this study were preliminary as the FLMI model is newly developed and this study addresses its inaugural implementation. As such, it has only shown these gains among students in the teacher-researcher's own classroom during one unit in one section of Algebra 2 during the 2017-2018 academic year. Further research is required in determining its long term effectiveness, its comparative effectiveness in regards to other teaching models, and its benefit for special needs students and English Language Learners (ELLs).

It is necessary to examine the outcome of broader implementation of the FLMI model over longer instructional periods, additional sections of the teacher-researcher's courses, other Algebra 2 teacher's courses, and other mathematics courses. Such research will involve additional time and faculty, but could provide data that will serve to analyze the capability of the FLMI model to improve student performance and perception of application-based tasks outside of the quadratics unit and in classes outside the teacher-researcher's own classroom. As the aforementioned action plan is implemented, it is important to continue collecting and analyzing data to determine the effectiveness of the FLMI model on a broader scale. Doing so will address this need.

Additionally, the FLMI model must be analyzed in comparison to other teaching models in place both in the teacher-researcher's classroom as well as in the classrooms of her colleagues. While the FLMI model resulted in significant academic gain in this study, it is not without consideration that other teaching models may have resulted in similar success. It is necessary to examine the teaching models used in other mathematics classrooms and to examine their success in comparison to the FLMI model. Further research is needed in determining the current models in place in mathematics classrooms at BHS and the outcomes of the use of each of these models in comparison to those of the FLMI model. Also, the teacher-researcher's own dispositions throughout the study may have confounded the results of this study. For this reason, replication of the study within the teacher-researchers classroom alongside those of other teachers is also necessary.

Furthermore, the FLMI model may serve additional purposes in improving success among special need students and ELLs. Further research may shed light on the effectiveness of the FLMI model in these scenarios. As the action plan is implemented, it is possible to address the effectiveness of the model for special needs students as well as ELLs through targeted data analysis.

During the data analysis of the present study, statistical analysis pointed towards higher levels of success in using the FLMI model among those students scoring in upper 50% than of those in the lower 50%. It is necessary to further study this model as it pertains to both higher and lower performing students to determine the effectiveness of the model among all learners and to seek opportunities to improve the model for those in the lower 50%. As with the investigation into the effectiveness of this model for special needs students and ELLs, a target data analysis may assist in determining the implications of this statistical finding.

Conclusion

This DiP has evaluated the FLMI model as a remedy for the PoP. Specifically it has addressed the effectiveness of the FLMI model in regards to improving student perception of and performance on application-based tasks in algebra. Chapter One: "Overview of the Dissertation in Practice" discussed the PoP, RQ, purpose statement, and a framework for this study. Chapter Two: "Review of Related Literature" further discussed related literature and theories of the FLF and FLMI model as well as the connected epistemologies and pedagogical practices. Chapter Three: "Methodology" outlined the process for data collection, data recording/coding, and data analysis for this study. Chapter Four: "Findings, Discoveries, Reflections, and Analyses" presented and discussed the data collected to describe the effects of the FLMI model while relating these results to the established PoP in order to answer the research question. Chapter Five: "Conclusions and Suggestions for Future Research" has examined the role of the teacher-researcher as a curriculum leader, the need for future research regarding the FLMI model, and an action plan for doing so.

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APPENDIX A

INSTITUTIONAL REVIEW BOARD APPROVAL

UNIVERSITY OF
SOUTH CAROLINA

OFFICE OF RESEARCH COMPLIANCE

INSTITUTIONAL REVIEW BOARD FOR HUMAN RESEARCH
APPROVAL LETTER for EXEMPT REVIEW

Susan Burnett
College of Education
Department of Instruction & Teacher Education / Curriculum & Instruction
Wardlaw
Columbia, SC 29208

Re: **Pro00069590**

This is to certify that the research study, "***The Effect of the Functional Linguistics of Mathematics Instruction (FLMI) Model on Quadratic Application Skills in Algebra***," was reviewed in accordance with 45 CFR 46.101(b)(**1**), the study received an exemption from Human Research Subject Regulations on **7/21/2017.** No further action or Institutional Review Board (IRB) oversight is required, as long as the study remains the same. However, the Principal Investigator must inform the Office of Research Compliance of any changes in procedures involving human subjects. Changes to the current research study could result in a reclassification of the study and further review by the IRB.

Because this study was determined to be exempt from further IRB oversight, consent document(s), if applicable, are not stamped with an expiration date.

All research related records are to be retained for at least three (3) years after termination of the study.

The Office of Research Compliance is an administrative office that supports the University of South Carolina Institutional Review Board (USC IRB). If you have questions, contact Arlene McWhorter at arlenem@sc.edu or (803) 777-7095.

Sincerely,

Lisa M. Johnson
IRB Assistant Director

APPENDIX B

RESEARCH SETTING APPROVAL

BEREA HIGH SCHOOL
Greenville County Schools
201 Burdine Drive – Greenville, SC 29617
864-355-1600—864-355-1625 fax—www.greenville.k12.sc.us

July 12, 2017

Mr. Mike Noel, Principal
Berea High School
201 Burdine Drive
Greenville, SC 29617

Dear Mr. Noel:

As a doctoral candidate at the University of South Carolina, I aim to conduct an action research project in my classroom during second semester this year. My research is grounded in functional linguistics and mathematics literacy and involves bookending my daily mathematics-skill instruction with literacy strategies. My pre-instruction literacy strategy will include vocabulary, syntax, and multiple representations. My post-instruction literacy strategy will assess student learning through the use of socio-mathematics assessments. Socio-mathematics assessments are application-based and require the learner to communicate their mathematical problem solving process either verbally or in writing. Students will be take a pre-test and post-test of quadratic applications. Data from each test will be compared to assess the efficacy of the instructional model. Parents will be informed of the research project and my intent to use the collected data for the completion of my dissertation. School and students' names and identifying information will be removed from all data prior to inclusion in my dissertation. I intend to conduct this research in Algebra 2 and during Unit 4: Quadratic Functions.

Please indicate your approval of my proposed study by signing below. Thank you.

Sincerely,

Susan Ray Burnett

Mr. Mike Noel, Principal, Berea High School

APPENDIX C

STUDENT ASSENT LETTER

Dear Student,

Your class has been selected to participate in a research study on a new teaching method. This teaching method involves mathematics literacy and will be used to teach one unit in our Algebra 2 curriculum. This teaching model is expected to assist you in making progress towards meeting your academic goals by improving your skills with mathematics. Your participation in this study will assist me in developing future instruction for this class and future classes.

You will take a pretest before beginning the unit and a posttest at the end of the unit. Your scores on each will be compared to evaluate the effectiveness of the teaching method. As a student-participant in this research, your test scores will be documented and reported to my research institution, The University of South Carolina, and to Greenville County School District. However, your name will be removed from all publications and confidentiality is ensured.

I am requesting your participation in this research. However, you have the right to refuse to participate. If you choose not to participate, your data will not be included in any publication of this study. However, you will still be responsible for completion of all assignments in the unit of study as you are still a student in the class and are to be held accountable for mastering the content of the course. Refusal to participate in the study will not result in discrimination or unfair bias of any kind.

Please indicate your desire to be included or not to be included in this research study and sign below.

Thank you,
Mrs. Burnett

___ I am willing to participate in this study. ___ I do not wish to participate in this study

Name: ______________________ Date: ___________ Signature: _____________________

APPENDIX D

PARENT CONSENT LETTER

Dear Parent,

Your child's class has been selected to participate in a research study on a new teaching method. This teaching method involves mathematics literacy and will be used to teach one unit in our Algebra 2 curriculum. This teaching model is expected to assist your child in making progress towards meeting his/her academic goals. His/her participation in this study will assist me in developing future instruction for his/her class and future classes.

He/she will take a pretest before beginning the unit and a posttest at the end of the unit. His/her scores on each will be compared to evaluate the effectiveness of the teaching method. As a student-participant in this research, his/her test scores will be documented and reported to my research institution, The University of South Carolina, and to Greenville County School District. However, his/her name will be removed from all publications and confidentiality is ensured.

I am requesting your permission for your child's participation in this research. If you choose to deny permission, your child's data will not be included in any publication of this study. However, he/she will still be responsible for completion of all assignments in the unit of study as he/she is still a student in the class and are to be held accountable for mastering the content of the course. Failing to participate in the study will not result in discrimination or unfair bias of any kind.

Please indicate your desire to allow/deny your child permission to be included in this research study and sign below.

Thank you,
Mrs. Burnett

___ I allow my child to participate. ___ I do not wish for my child participate.

Name: ______________________ Date: ___________ Signature: ____________________

APPENDIX E

WORD PROBLEMS PRE- and POST- SURVEY

1. I feel confident when I see a word problem on a quiz or test.

	1	2	3	4	5	
Strongly Disagree	○	○	○	○	○	Strongly Agree

2. I know how to read a word problem and identify the important information.

	1	2	3	4	5	
Strongly Disagree	○	○	○	○	○	Strongly Agree

3. If someone helps me to set up the calculations for a word problem, I can solve it.

	1	2	3	4	5	
Strongly Disagree	○	○	○	○	○	Strongly Agree

4. I generally know how to set up the calculations for a word problem without help.

	1	2	3	4	5	
Strongly Disagree	○	○	○	○	○	Strongly Agree

5. I enjoy doing word problems in Algebra.

	1	2	3	4	5	
Strongly Disagree	○	○	○	○	○	Strongly Agree

6. Word problems are more difficult than math problems that are not word problems.

	1	2	3	4	5	
Strongly Disagree	○	○	○	○	○	Strongly Agree

7. I prefer to do problems that involve real world scenarios than problems that do not.

	1	2	3	4	5	
Strongly Disagree	○	○	○	○	○	Strongly Agree

8. I prefer projects that involve real world problems instead of quizzes or tests that do not.

	1	2	3	4	5	
Strongly Disagree	○	○	○	○	○	Strongly Agree

9. I prefer a teacher who explains how math relates to the real world than one who focuses only on how to do calculations.

	1	2	3	4	5	
Strongly Disagree	○	○	○	○	○	Strongly Agree

10. Describe your feelings about word problems and real world scenarios in math.

____

____

11. When you come to a word problem on a test or a quiz what do you generally do?

____

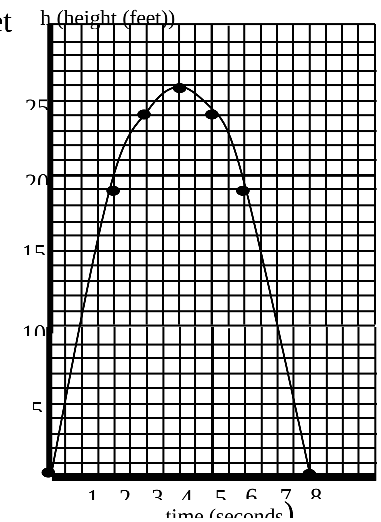
____

APPENDIX F

PRE-TEST

Algebra 2 **Name:** ______________________________
Quadratic Functions Word Problems Pre-test

The graph at the right shows the **height *h*** in feet of a small rocket ***t* seconds** after it is launched. The path of the rocket is given by the equation: $\mathbf{h = -16t^2 + 128t + 0}$.



1. How long is the rocket in the air? __________

2. What is the greatest height the rocket reaches? ____

3. About how high is the rocket after 1 second? _______

4. After 2 seconds,
   a. about how high is the rocket?_________

   b. is the rocket going up or going down? ________

5. After 6 seconds,
   a. about how high is the rocket? _______

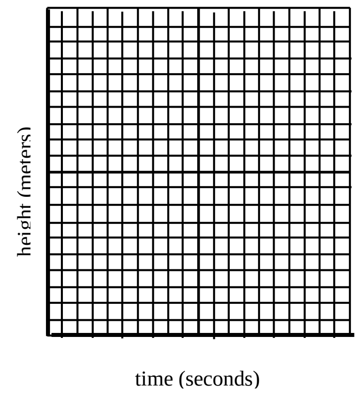
   b. is the rocket going up or going down? ________

6. Using the equation, find the **exact** value of the height of the rocket at 2 seconds.

7. A ball is thrown in the air. The path of the ball is represented by the equation **$h = -t^2 + 8t$**. Graph the equation.

What is the maximum height of the ball?____________

How long is the ball above 7 meter? ________________



8. After *t* seconds, a ball tossed in the air from the ground level reaches a height of *h* feet given by the equation **$h = -16t^2 + 144t + 3$**.

a. What was the height of the ball when it was thrown?

b. When does the ball reach its maximum height?

c. What is the height of the ball when it reaches its maximum height?

d. When does the ball reach the ground?

9. A rocket carrying fireworks is launched from a hill 80 feet above a lake. The rocket will fall into lake after exploding at its maximum height. The rocket's height above the surface of the lake is given by

   $\mathbf{h = -16t^2 + 64t + 80}$.

   a. What was the height of the rocket when it was launched?

   b. When does the rocket reach its maximum height?

   c. What is the height of the rocket when it reaches its maximum height?

   d. When does the rocket reach the lake?

10. A rock is thrown from the top of a tall building. The distance, in feet, between the rock and the ground t seconds after it is thrown is given by
$d = -16t^2 - 4t + 382$.

a. What was the height of the rock when it was thrown?

b. When does the rock reach its maximum height?

c. What is the height of the rock when it reaches its maximum height?

d. When does the rock hit the ground?

APPENDIX G

THEMATIC INVESTIGATION

Algebra 2 Name: ______________________________
Springboard Dive

Mrs. Burnett has been asked to photograph the 2020 Olympic Diving team. She knows that the function $h(t) = -5t^2 + 10t + 3$ represents the height of a diver above the water (in meters), t seconds after the diver leaves the springboard. (You know because she's super smart and all.)

So, what's the problem? Well, Mrs. Burnett is kind of clumsy and fell coming into the school this morning to teach all of her fabulous students. Unfortunately, she suffered a little brain damage because of her fall. She needs to figure a few things out before she meets up with the team to do their photo shoot but her brain is not quite functioning like it used to…stupid speed bump.

1. The team has asked that they each have a picture of themselves just prior to their jump off of the board. Mrs. Burnett will need to set a tripod up to capture these images. But, she needs to know how high the diving board is in order to set the tripod up. How high above the water's surface is the diving board?

2. The divers have also asked for an image of each of them just as they hit the water's surface at the end of their dive. Mrs. Burnett will need to know the exact timing to make this shot. How many seconds will pass from the time the diver jumps off the board until they hit the water?

3. Mrs. Burnett would also like to have an image of each diver before they hit the water, but will need to use the tripod to take this image. Since she only has one decent tripod, she will need to use the same tripod that she set up for the images mentioned in number 1. Therefore, she will need to know when the diver will be at the exact same height that he/she was at when she began her dive. When will the diver again be at the same height as the board?

4. Lastly, Mrs. Burnett needs to know the amount of time at which the diver will reach the peak of their dive in order to capture an image of the diver in mid air. How long after beginning the dive will the diver reach his/her maximum height?

5. Please draw one graph to represent all of the above situations and label each point that Mrs. Burnett will capture on camera.

6. Just in case Mrs. Burnett's brain injury worsens, please also list each of the points in a table that will ensure that Mrs. Burnett understands exactly when to take each picture and at what height the images will need to be taken.

7. And, just in case Mrs. Burnett is completely worthless and can't even read a chart, please explain each photograph that will need to be taken in a sentence. Explain what the image will be of, what time it will need to be taken, and what height it will need to be taken at.

APPENDIX H

ANTICIPATION GUIDE

1. Could a graph help me with any parts of the thematic investigation?

   a. Which parts?

2. Could a table of values help me with any parts of the thematic investigation?

   b. Which parts?

3. Could an equation help me with any parts of the thematic investigation?

   a. Which Parts?

4. What skills do I already have that will help me to solve the problems in the thematic investigation?

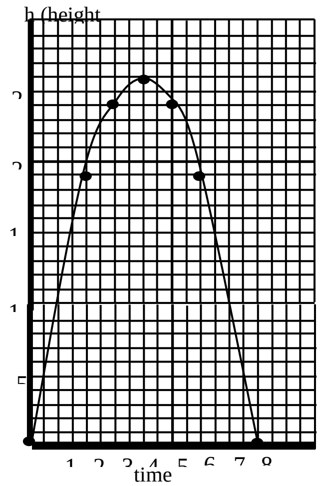
5. What do I need to learn more about to help me in the thematic investigation?

APPENDIX I

POST-TEST

Algebra 2 **Name:** ______________________________
Quadratic Functions Word Problems Post-test

The graph at the right shows the **height *h*** in feet of a small rocket ***t* seconds** after it is launched. The path of the rocket is given by the equation: $\mathbf{h = -16t^2 + 128t + 0.}$



1. How long is the rocket in the air? __________

2. What is the greatest height the rocket reaches? ____

3. About how high is the rocket after 2 second? _______

4. After 3 seconds,
   a. about how high is the rocket?_________

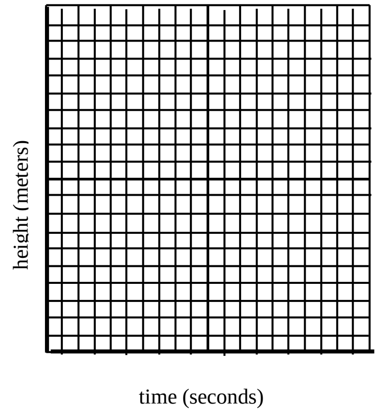
   b. is the rocket going up or going down? ________

5. After 5 seconds,
   a. about how high is the rocket? _______

   b. is the rocket going up or going down? ________

6. Using the equation, find the **exact** value of the height of the rocket at 3 seconds.

7. A ball is thrown in the air. The path of the ball is represented by the equation **$h = -t^2 + 10t$**. Graph the equation.



What is the maximum height of the ball?____________

How long is the ball above 7 meter? ________________

8. After *t* seconds, a ball tossed in the air from the ground level reaches a height of *h* feet given by the equation **$h = -16t^2 + 120t + 5$**.

a. What was the height of the ball when it was thrown?

b. When does the ball reach its maximum height?

c. What is the height of the ball when it reaches its maximum height?

d. When does the ball reach the ground?

9. A rocket carrying fireworks is launched from a hill 80 feet above a lake. The rocket will fall into lake after exploding at its maximum height. The rocket's height above the surface of the lake is given by

$h = -16t^2 + 128t + 100$.

a. What was the height of the rocket when it was launched?

b. When does the rocket reach its maximum height?

c. What is the height of the rocket when it reaches its maximum height?

d. When does the rocket reach the lake?

10. A rock is thrown from the top of a tall building. The distance, in feet, between the rock and the ground t seconds after it is thrown is given by
$\mathbf{d = -16t^2 - 32t + 200.}$

a. What was the height of the rock when it was thrown?

b. When does the rock reach its maximum height?

c. What is the height of the rock when it reaches its maximum height?

d. When does the rock hit the ground?